Poster 1

April 29 (Monday) / 15:10 ~ 16:30 / Capri room

Modeling

P1-1.1 / Temporal study of dual frequency single surface multipactor by multiparticle Monte Carlo simulations

Asif Iqbal (Michigan State University, USA), John Verboncoeur (Michigan State University, USA), Patrick Wong (Michigan State University, USA), Peng Zhang (Michigan State University, USA)

This work investigates the temporal physics of multipactor discharge on a single dielectric surface by one-dimensional multiparticle Monte Carlo (MC) simulator with adaptive time steps. The study shows that the presence of a second carrier frequency of the rf electric field changes the saturation level and temporal oscillation pattern of the normal surface field. It is found that the instantaneous normal surface field and the multipactor electron population remains at a lower value for a longer duration within an rf period for dual frequency operation than for single frequency operation.

P1-1.2 / 3-D EM PIC simulation study on low-frequency oscillation in a fusion gyrotron

Ming-Chieh Lin (Hanyang University, Korea), David N. Smithe (Tech-X Corporation, USA)

In a previous study, it was found that not only magnetic compression profile but initial thermal velocities of electrons play an important role in causing a low frequency oscillation (LFO) in the operation of a magnetron injection gun (MIG) employed in an MIT fusion gyrotron. An unphysical particle boundary condition, i.e., large initial thermal velocities of electrons, had to be assumed to produce the LFO in the 3-D electromagnetic (EM) particle-in-cell (PIC) simulation. In this work, we have included the gyrotron cavity along with the MIG as well as a large vacuum envelope representing the vacuum chamber similar to that employed in the MIT experiments. In the EM PIC simulation, it is found that the momentum of electrons is suppressed by the space charge due to the vacuum envelope. For the first time, without unphysical approximations, the LFO could be reproduced in the 3D time domain EM PIC simulations. The initial velocity spread at the cathode temperature is assumed in this simulation in contrast to an unphysical larger velocity spread formerly used.

P1-1.3 / Analysis of High Frequency Characteristics of Sheet Beam Rectangular Waveguide Grating Operating in High-Order Mode

Xiaofei Li (University of Chinese Academy of Science / Chinese Academy of Science, China), Qianzhong Xue (University of Chinese Academy of Science / Chinese Academy of Science, China), Ding Zhao (Chinese Academy of Science, China)

For the rectangular waveguide grating slowwave structure, the dispersion relation was obtained by the eigen-function method. The coupling impedance and the Ohmic loss were derived from the relevant equations. Two theoretical models were studied by comparing their calculation results of the HF characteristics of the rectangular waveguide grating slow wave structure with those obtained by HFSS code and CST-MWS. The HF characteristics of the largersize SWS operating in the high order mode and the SWS operating in the fundamental mode were compared, and the results presented in this paper demonstrate the possibility of using the highorder mode in devices.

P1-1.4 / An Emission Model Considering the Thermal Velocity of Electrons Under the Constraint of Spherical Surface

Xiaobing Wang (University of Electronic Science and Technology of China, China), Quan Hu (University of Electronic Science and Technology of China, China), Yulu Hu (University of Electronic Science and Technology of China, China), Xiaofang Zhu (University of Electronic Science and Technology of China, China), Bin Li (University of Electronic Science and Technology of China, China)

In order to calculate the thermal velocity effects of electrons in TWT, this paper proposes a model that considers the spherical cathode to constrain the discrete macro electron trajectories calculated by the Lambert's law mentioned in MICHELLE[1]. The model uses the optics principle to correct the emission direction of the discrete trajectories of electrons. This paper will introduce the emission model and discuss some of its limitations.

P1-1.5 / Mechanics Simulator: An Advanced 3D FE Vibration Simulation Tool for Microwave Tubes

Junhui Yin (University of Electronic Science and Technology of China, China), Li Xu (University of Electronic Science and Technology of China, China), Zhonghai Yang (University of Electronic Science and Technology of China, China), Bin Li (University of Electronic Science and Technology of China, China)

The structures of microwave tube are very fine and complex. Small mechanical perturbations of structures can possibly lead to electrical failure of the microwave tube and even cause the structures of the microwave tube destroyed. Designers need to study the reliability and stability of microwave tube and understand their instabilities in current designs and predict material failure for future designs under all operatinzg environment conditions. In this paper, a three-dimensional mechanical vibration analysis numerical simulation software MCS, which consists of design environment, free vibration analysis simulator and random vibration analysis simulator, is developed based on finite element method and CAD/CAE integrated system. The developed software has been applied to traveling wave tubes design and been found to shorten the design cycle significantly compared with commercial software ANSYS.

P1-1.6 / A Three-Dimensional Model of Beam-Wave Interaction in a Coupled-Cavity TWT

Xinhe Wang (Chinese Academy of Science, China), Yu Fan (Chinese Academy of Science, China), Gang Wang (Chinese Academy of Science, China), Jirun Luo (Chinese Academy of Science, China), Min Zhu (Chinese Academy of Science, China), Wei Guo (Chinese Academy of Science, China)

A frequency-domain 3-D model of the beam-wave interaction in coupled-cavity traveling-wave tubes(CC-TWTs) is presented. The model provides self-consistent solutions of Maxwells equations with electron equations of motion. Some nonlinear effects in the interaction process could be revealed.

P1-1.7 / Research on Acceleration of a Electron Gun Simulation Module

Hang Du (Southeast University, China), Hehong Fan (Southeast University, China), Yanxiao Guo (Southeast University, China), Xiaohan Sun (Southeast University, China)

Simulation speed is a key performance for simulation software to be used practically, especially for used in optimizations and high-precision simulations. To accelerate simulation speed of our former electron gun simulation software module, EGunNoiseSim, a time domain simulation software module programmed based on MATLAB, we tried two methods to accelerate it. First the existing MATLAB-based program is translated into a C language program; then a parallel computing processing scheme based on CUDA is used to further improve its simulation efficiency. Simulation results show that the speed of the new simulation program based on C can be 2 times faster than the original program; and by using parallel computing technique, the simulation speed can be improved further to 4 to 14 times faster. To demonstrate the function of the simulation module, evolution of the particle distribution were shown, which proved the feasibility of the adaptation work.

Poster 1

April 29 (Monday) / 15:10 ~ 16:30 / Capri room

TWTs / SWS / THz sources

P1-2.1 / Theoretical Investigation into an Ultra-Wideband Helix Traveling-Wave Tube

Xuanming Zhang (University of Electronic Science and Technology of China, China), Guang Yang (University of Electronic Science and Technology of China, China), Hailin Ou (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China), Yanheng Zhao (East China Optpelectronic Technology Institute of Anhui, China), Qingdong Deng (East China Optpelectronic Technology Institute of Anhui, China), Zhaochang He (East China Optpelectronic Technology Institute of Anhui, China)

In this paper, a new ultra-wideband (18-40 GHz) helix traveling-wave tube (TWT) is proposed. The transmission characteristics and high frequency characteristics are simulated by using CST and HFSS, respectively. It is shown that the voltage standing wave ratio (VSWR) of the input/output couplers is below 1.5 in the operating band. In order to improve the whole performances of the proposed helix TWT, a helix pitch step method is employed to optimize the slow-wave structure (SWS) by using a 2.5-D large signal code to simulate nonlinear beam-wave interaction. When the operating voltage and beam current are 10 kV and 100 mA, respectively, and the length of the helix SWS is 150 mm, it is observed from the simulation results that the saturated output power and saturated gain are over 80 W and 40 dB. This proposed device is very useful for application to electronic warfare.

P1-2.2 / A Key Design and Experiment of a Broadband High-power Pulsed Helix TWT

Jiangna Jiao (Beijing Vacuum Electronics Research Institute, China), Li Qiu (Beijing Vacuum Electronics Research Institute, China), Lei Zhang (Beijing Vacuum Electronics Research Institute, China), Baoliang Hao (Beijing Vacuum Electronics Research Institute, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China), Yanmei Wang (Beijing Vacuum Electronics Research Institute, China),

This paper describes a broadband high-power helix traveling wave tube(TWT). A key design of a broadband high-power pulsed helix TWT is put forward, and tested by simulation and experiment. The simulated results show that the composite slow-wave structure(SWS) with rectangular vanes and T-shape vanes has higher interaction impedance and lower harmonic-ratio. Moreover, the experimental results are given that the key design has higher output power at medium and high frequency stage. While the minimum output power is 1kW among the frequency of 7.5 GHz – 18 GHz with 5% pulsed duty cycle. Efficiency is over 30%

and harmonic-ratio is less than -6 dBc. The TWT has overall dimensions of 36 mm wide by 310 mm long by 39 mm tall and weighs less than 1kg which has vacuum pump to ensure function of maintenance-free.

P1-2.3 / Design of a Sheet Beam Electron Gun for 850GHz Staggered Double Vane Traveling Wave Tube

Wei Shao (University of Electronic Science and Technology of China, China), Hanwen Tian (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Zhigang Lu (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China), Tao Tang (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China, China), Yanyu Wei (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China)

A sheet beam electron gun for 850GHz staggered double vane TWT is designed in this paper. The designed beam achieves a beam current of 20mA, beam voltage of 28.1kV and cross-sectional dimension of 0.12mm×0.03mm. And the beam transmission efficiency with a designed uniform permanent magnetic field is achieved with 95.7%. Finally the beam-wave interaction with above parameters is calculated and the output power is obtained with 33.8mW.

P1-2.4 / Electron Optical System with Uniform Magnetic Field for 220 GHz Sheet Beam TWT

Shengkun Jiang (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China, China), Xin Wang (University of Electronic Science and Technology of China, China), Guang Yang (University of Electronic Science and Technology of China, China), Shengming Li (Nanjing Sanle microwave Technology Development Co., Ltdc), Zhanliang Wang (University of Electronic Science and Technology of China, China), Tao Tang (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China)

Based on the high-frequency structure of the T-shape staggered double-vane, an electron optical system (EOS) with uniform magnetic field for 220 GHz sheet beam TWT is formed with the help of 3-D simulation software CST. The simulation results show that the current and anode voltage of the electron gun are 158 mA and 22.1 kV, respectively, and the electron beam transmission efficiency is 97.2% under the axial magnetic field of 0.38 T in a 37 mm length drift tube with 0.8 mm × 0.15 mm beam tunnel.

P1-2.5 / Analytical Solution of Beam-wave Interaction Hot Dispersion Equation with Cyclotron Resonance Enhancement Effect in a Planar Metallic Grating

Jing Wang (Research and development center of Space TWT Beijing / Chinese Academy of Sciences, China), Yu Fan (Chinese Academy of Sciences, China), Jirun Luo (Research and

development center of Space TWT Beijing / Chinese Academy of Sciences, China), Wang Gang (Chinese Academy of Sciences, China)

Based on Maxwell's equation and linear Volasov equation, the planar metallic grating beam-wave interaction 'hot' dispersion equation considering both cyclotron resonance and Cherenkov resonance has been obtained, which can be used to verify the effect of cyclotron resonance on beam wave interaction gain and frequency band, etc in TWT.

P1-2.6 / Simulation of ion noise in traveling wave tubes

Qing Zhou (University of Electronic Science and Technology of China / Hebei Key Laboratory of Compact Fusion, China), Huarong Gong (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China)

In this paper, the simulation of ion noise in periodic permanent magnetic field traveling wave tubes is conducted. Through calculation, it is found that the residual gas in the traveling wave tubes is ionized, and the diagnostic of the ion number shows an obvious period which corresponds to the fluctuation of the average kinetic energy.

P1-2.7 / Analysis of Thermal Loss in the THz Sheet Beam Folded Waveguide TWT

Fengying Lu (University of Chinese Academy of Sciences / Chinese Academy of Sciences, China), Chao Zhao (University of Chinese Academy of Sciences / Chinese Academy of Sciences, China), Yong Wang (University of Chinese Academy of Sciences / Chinese Academy of Sciences, China)

The sheet beam (SB) tunnel was introduced in the terahertz (THz) folded waveguide (FW) traveling wave tube (TWT) for power enhancement. In this paper, the thermal loss in the SB FW-TWT operating at 220GHz was studied with the help of Particle-in-cell (PIC) simulation. The amplification performance of the SB-TWTs constructed with lossy metal and PEC was compared. The main influencing factors on the thermal loss, including particle collision loss and ohmic loss, in the SB FW-TWT were observed and analyzed. The results give a closer look into the energy transfer process and technical assistance in parameter optimization.

P1-2.8 / Study of Sheet Beam Electron Optical System and Energy Coupler for Wideband 340GHz TWT

Kaicheng Wang (University of Electronic Science and Technology of China, China), Wei Shao (University of Electronic Science and Technology of China, China), Hanwen Tian (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Zhigang Lu (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China), Tao Tang (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China, China), Yanyu Wei

(University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China)

An electron optical system with long-range low emission current density electron gun and H-plane double-slit coupling input-output RF coupler are studied for 340GHz sheet beam staggered double vane traveling wave tube (TWT). The long-range sheet beam electron gun can reduce the difficulties in assembling and adjusting of the whole magnetic system. Low emission current density can reduce the processing difficulty and improve the life of the electron gun. The bandwidth of the microwave circuits with H-plane double-slit input and output couplers is so broad that can approach 45GHz. Taking the high frequency loss of copper into account, the beam-wave interaction simulation shows that the whole design provides 14.6W of output power and 31.6dB gain at 340GHz.

P1-2.9 / Design and simulation of a 650 GHz Folded Waveguide Traveling Wave Tube

Xu shouxi (Chinese Academy of Sciences, China)

650 GHz FWTWT designs have been presented using 3-D simulations. The preliminary simulation results show that the amplifier can produce an output power of over 1W, 23dB gain, and a 10GHz bandwidth where beam voltage and current are 16kV and 10mA, respectively.

P1-2.10 / Study on Radial Convergent Beam Angular Mirror Symmetrical Log-Periodic Strip Line SWS

Xinyi Li (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Tenglong He (University of Electronic Science and Technology of China, China), Hexin Wang (University of Electronic Science and Technology of China, China), Zijun Chen (University of Electronic Science and Technology of China, China), Duo Xu (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China), Yurong Liu (Nanjing Sanle Electronics Group CO.,LTD, China), Zhiqiang Gao (Nanjing Sanle Electronics Group CO.,LTD, China), Daxi Ji (Nanjing Sanle Electronics Group CO.,LTD, China)

A novel slow wave structure (SWS) called radial convergent beam angular mirror symmetrical log-periodic strip line SWS is presented in this paper. The structure can be considered as the azimuthal integration of two angular log-periodic strip line SWSs. The emission density of the cathode can be reduced by the adoption of radial convergence beam. The SWS can provide the gain of ~15dB at the frequency range of (35~36) GHz. The results show that the angular mirror symmetrical log-periodic strip line SWS provides a possibility for the application of larger open angle angular log-periodic SWS.

P1-2.11 / Study on Broadband Ridge-Loaded Symmetrical Conformal Microstrip Meander Line Traveling Wave Tube at Ka-Band

Duo Xu (University of Electronic Science and Technology of China, China), Hexin Wang (University of Electronic Science and Technology of China, China), Tenglong He (University of Electronic Science and Technology of China, China), Xinyi Li (University of Electronic Science and Technology of China, China), Zhigang Lu (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China)

In order to broaden the bandwidth of the Ka-band traveling wave tube (TWT), a novel slow wave structure (SWS) named ridge-loaded symmetrical conformal microstrip meander line (RSCMML) is proposed in this paper. The simulation results indicate that the novel SWS has good transmission characteristics and weak dispersion characteristics. In addition, the beamwave interaction simulation results show that the maximal output power of the optimized novel TWT is 94 W at the frequency of 34 GHz, the maximum gain and the maximum radio frequency (RF) efficiency are 25.7 dB and 16.1% respectively, and the 3-dB bandwidth can cover the whole Ka-band entirely.

P1-2.12 / Design of a 0.67THz Folded Waveguide TWT

Huang Yinhu (China Academy of Engineer Physics, China), Rui Song (China Academy of Engineer Physics, China), Hu Peng (China Academy of Engineer Physics, China), Jiang Yi (China Academy of Engineer Physics, China), Wenqiang Lei (China Academy of Engineer Physics, China), Chen Hongbin (China Academy of Engineer Physics, China)

A design of 0.67THz folded waveguide TWT (FWTWT) is presented in this paper aims to develop a compact, efficient and reliable THz source and boost the application of THz. Slow-wave circuit, electron transmission system and energy coupling structure are designed with deep theoretical analysis and numerical simulation. The result shows, the maximum output power is 158mW and the maximum gain is 22dB with more than 10GHz of -3dB bandwidth.

P1-2.13 / A 340GHz 20W Staggered Double Vane Traveling Wave Tube

Xianbao Shi (The 41th institute of CETC, China), Weihua Xiong (The 41th institute of CETC, China), Chunhua Wen (The 41th institute of CETC, China)

Based on the staggered double vane (SDV) slow wave structure (SWS), a 340 GHz traveling wave tube (TWT) amplifier is designed in this work. The simulation results show that the interaction impedance of the optimized SWS is greater than 4 Ohms in the frequency range from 320 GHz to 350 GHz. And the amplification property of the TWT is that the output power is more than 13 W, corresponding output gain is more than 31.5 dB in the whole working frequency band.

P1-2.14 / Research on High Gain W Band Folded Waveguide Traveling Wave Tube

Xianbao Shi (The 41th institute of CETC, China), Weihua Xiong (The 41th institute of CETC, China), Chunhua Wen (The 41th institute of CETC, China)

In this work, a W band high gain traveling wave tube (TWT) is designed based on folded waveguide (FWG) slow wave structure (SWS). The simulation results show that the optimized W band FWG SWS has a relative wide operating band from 89 GHz to 103 GHz. And the interaction characteristics show that designed W band FWG TWT has a very high gain which is more than 36 dB in the whole frequency band.

P1-2.15 / Transmission Characteristics of 220 GHz T-shape Staggered Double-Vane Slow Wave Structure

Guang Yang (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China, China), Shengkun Jiang (University of Electronic Science and Technology of China, China), Daxi Ji (Nanjing Sanle Group Co., Ltd, China), Tao Tang (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China)

In this paper, a T-shape staggered double-vane slow wave structure (SDVSWS) for 220 GHz sheet beam travelling-wave tube (TWT) is studied. The simulated transmission characteristic results of the whole SDVSWS with the input and output couplers are investigated by using the CST. The transmission coefficient S_{21} is greater than -7.5 dB and the reflection coefficient S_{11} is below -20 dB from 213 GHz to 230 GHz, and the attenuation constant of the whole SDVSWS is below 1.6 dB/cm in the same frequency range. The designed SDVSWS has a good performance for 220 GHz sheet beam TWT, which is of great importance for applications such as radar, communications, security, and imaging.

P1-2.16 / Study of Two-section Rectangular Beam TWTs Based on Folded Waveguide

Fengying Lu (University of Chinese Academy of Sciences / Chinese Academy of Sciences, China), Rui Zhang (Chinese Academy of Sciences, China), Yong Wang (University of Chinese Academy of Sciences / Chinese Academy of Sciences, China)

For the purpose of improving the output power based on folded waveguide (FW) traveling wave tube (TWT), a two-section rectangular beam (RB) FW-TWT is presented in this paper. A 3-D particle-in-cell (PIC) simulation CST is applied to analyze the performance of a 220GHz RB-FW. The relation between interaction length and output power of normal one-section RB-TWT is investigated. Then a RB-TWT comprising of two sections is constructed and 100W output power can be achieved. The effects of attender material on the output power is studied. The dielectric factor is recommended to be 8.5 to achieve higher output power.

P1-2.17 / Design of a W-band traveling-wave tube based on sine waveguide slow-wave structure with sheet electron beam

S. Z. Fang (University of Electronic Science and Technology of China, China), J. Xu (University of Electronic Science and Technology of China, China), X. Lei (University of Electronic Science and Technology of China, China), X. B. Jiang (University of Electronic Science and Technology of China, China), P. C. Yin (University of Electronic Science and Technology of China, China), L. Li (University of Electronic Science and Technology of China, China), G. X. Wu (University of Electronic Science and Technology of China, China), R. C. Yang (University of Electronic Science and Technology of China, China), Q. Li (University of Electronic Science and Technology of China, China), H. R. Yin (University of Electronic Science and Technology of China, China), L. N. Yue (University of Electronic Science and Technology of China, China), G. Q. Zhao (University of Electronic Science and Technology of China, China), W. X. Wang (University of Electronic Science and Technology of China, China), Y. B. Gong (University of Electronic Science and Technology of China, China), Y. Y Wei (University of Electronic Science and Technology of China, China), X. Xu (State Key Laboratory of Complex Electromagnetic Environment Effects on Electronics and Information System), Yang Liu (University of Electronic Science and Technology of China, China)

A W-band TWT based upon flat-roofed sine waveguide slow-wave structure is designed. The transmission characteristics of high frequency structure with input/output window show that the S_{21} is more than -4 dB and S_{11} is less than -16 dB. The beam-wave interaction results show that the output power is more than 40 W range from 90 GHz to 100 GHz with voltage of 19 kV and current density of 50 mA/cm^2.

P1-2.18 / Harmonic components measurement of TWT with rectangular waveguide output structure

Feng Zou (Chinese Academic of Sciences / University of Chinese Academy of Sciences, China), Xin'ai Liu (Chinese Academic of Sciences, China), Gang Wang (Chinese Academic of Sciences, China), Guoxing Miao (Chinese Academic of Sciences, China), FangFang Song (Science and Technology on Reliability Physics and Application Technology of Electronic Component Laboratory, China)

The results of output harmonic components measurements show great disagreement where rectangular waveguide is used as output port in hundred watts CW-TWT operating above X-band. Typical error of X-band TWT is larger than 12dB. This paper advanced a quasi-direct measurement method using signal spectrum analyzer (SSA), which measured harmonic components under pulse mode. The error is less than 3.5dB and can be improved by applying matched coax-waveguide convertor.

P1-2.19 / A 70W 81-86GHz E-band CW Travelling Wave Tube

Zhangxiong Zi (Beijing Vacuum Electronics Research Institute, China), Shishuo Liu (Beijing Vacuum Electronics Research Institute, China), Qingmei Xie (Beijing Vacuum Electronics

Research Institute, China), Shijing Li (Beijing Vacuum Electronics Research Institute, China), Jun Cai (Beijing Vacuum Electronics Research Institute, China), Shilu Zhao (Beijing Vacuum Electronics Research Institute, China)

BVERI has developed a 70W E-band travelling wave tube (TWT) to meet the demands of future high data rate wireless communication. The TWT is a periodic permanent magnet focused folded waveguide tube. It can produce over 75W continuous wave saturated output power over the range of 81-86GHz. With a single stage depressed collector, it can realize an efficiency over 16.7%. The test results of nonlinear phase shift and third order intermodulation of the tube are also presented in this paper.

P1-2.20 / Multiphysics analysis of Ka-band U-shaped microstrip line planar traveling wave tube

Gangxiong Wu (University of Electronic Science and Technology of China, China), Ruichao Yang (University of Electronic Science and Technology of China, China), Hairong Yin (University of Electronic Science and Technology of China, China), Xia Lei (University of Electronic Science and Technology of China, China), Qian Li (University of Electronic Science and Technology of China, China) Shuangzhu Fang (University of Electronic Science and Technology of China, China), Lingna Yue (University of Electronic Science and Technology of China, China), Jin Xu (University of Electronic Science and Technology of China, China), Guoqing Zhao (University of Electronic Science and Technology of China, China) , Wenxiang Wang (University of Electronic Science and Technology of China, China) Yubin Gong (University of Electronic Science and Technology of China, China), Yanyu Wei (University of Electronic Science and Technology of China, China), Yang Liu (Southwest China Research Institute of Electronic Equipment, China), Fei Shen (Hefei University of Technology, China)

In this paper, multiphysics field simulation is applied to analyze the temperature distribution of Ka-band Ushaped microstrip line planar TWT considering the thermal losses induced by ohmic loss and electron collision losses. The beam-wave interaction of the planar TWT is analyzed by using CST particle-in-cell (PIC) solver, at the same time the thermal losses distribution is recorded, which will be the heat source. The simulation results show that the high temperature with a peak value of 263 ℃.

P1-2.21 / Study of Slow Wave Structure with Double Corrugated Waveguide Shielded by Photonic Crystals

Hongxia Yi (Chinese Academy of Sciences, China), Liu Xiao (Chinese Academy of Sciences, China), Mingguang Huang (Chinese Academy of Sciences, China)

A Double Corrugated Waveguide Shielded by Photonic Crystal (PhC) wall is proposed for effective beam-wave interaction with a circular beam at terahertz frequency. Numerical results reveal that the The phase velocity and Pierce interaction impedance for Double Corrugated Waveguide Shielded by Photonic Crystals are higher in the frequency of Photonic band gap compared with conventional Double Corrugated Waveguide.

P1-2.22 / Study on a Microfabrication W-band Planar Meander-Line Slow-Wave Structure

Andrey Starodubov (Institute of Radio Engineering and Electronics RAS / Saratov State University, Russia), Alexey Serdobintsev (Saratov State University, Russia), Roman Torgashov (Institute of Radio Engineering and Electronics RAS / Saratov State University, Russia), Anton Pavlov (Saratov State University, Russia), Gennadiy Torgashov (Institute of Radio Engineering and Electronics RAS, Russia), Andrey Rozhnev (Institute of Radio Engineering and Electronics RAS, Russia) Viktor Galushka (Saratov State University, Russia), Peter Ryabukho (Saratov State University, Russia), Igor Bakhteev (JSC CIME, Russia), Sergei Molchanov (JSC CIME, Russia), Nikita Ryskin (Institute of Radio Engineering and Electronics RAS / Saratov State University, Russia)

Properties of a microfabricated W-band (75-110GHz) meander slow-wave structures (SWS) for low-voltage tubes with sheet electron beam are studied by numerical simulation and cold-test measurement. The SWS was microfabricated following previously published protocol based on magnetron sputtering and laser ablation processes. Transmission and reflection losses of proposed SWS were measured experimentally and evaluated numerically. The experimental results are in good agreement with the numerical ones.

P1-2.23 / Design of a quasi flat-roofed sine waveguide Slow-wave structure for 220GHz TWT

Xuebing Jiang (University of Electronic Science and Technology of China, China), Jin Xu (University of Electronic Science and Technology of China, China), Hairong Yin (University of Electronic Science and Technology of China, China), Shuanzhu Fang (University of Electronic Science and Technology of China, China), Pengcheng Yin (University of Electronic Science and Technology of China, China), Xia Lei (University of Electronic Science and Technology of China, China), Gangxiong Wu (University of Electronic Science and Technology of China, China), Ruichao Yang (University of Electronic Science and Technology of China, China), Guo Guo (University of Electronic Science and Technology of China, China), Lingna Yue (University of Electronic Science and Technology of China, China), Wenxiang Wang (University of Electronic Science and Technology of China, China), Guoqing Zhao (University of Electronic Science and Technology of China, China), Yanyu Wei (University of Electronic Science and Technology of China, China), Dazhi Li (Institute for Laser Technology, Japan), Fei Shen (Hefei University of Technology, China)

A novel quasi flat-roofed sine waveguide slow wave structure (SWS) is presented for the wideband highpower terahertz traveling-wave tube (TWT). The quasi flatroofed sine waveguide SWS (QFRSWG TWT) possesses the similar slow-wave characteristics with the flat-roofed sine waveguide SWS in the frequency range of 0.2-0.26THz. The beam-wave interaction results indicate that the TWT based upon this QFRSWG can generate the output power of 136W at 220GHz by using the sheet electron beam of 20.8kV and 100mA.

P1-2.24 / Preliminary Study of a New Meander Line for W-band TWT

Juan M. Socuéllamos (Lancaster University, United Kingdom), Rosa Letizia (Lancaster University,

United Kingdom), Roberto Dionisio (European Space Agency, The Netherlands), Claudio Paoloni (Lancaster University)

A new meander line topology for 71-76 GHz Traveling Wave Tubes is proposed. This new shape offers flatter dispersion relation and enhanced interaction impedance in comparison with the standard meander line. Results of the interaction impedance over the beam cross section and the effect of a meander line-to-waveguide coupler are also analyzed in this work.

P1-2.25 / Effect of Electron Beam Velocity Nonuniform on Helix TWT Output Performance

Changsheng Shen (Southeast University, China), Jin Zhang (Southeast University, China), Hehong Fan (Southeast University, China), Ningfeng Bai (Southeast University, China), Xiaohan Sun (Southeast University, China)

Due to the complex electromagnetic environment and cathode emission randomness in the helix TWT, the velocity magnitude and direction of electron beam from the electron gun to the slow wave structure are nonuniform. We define two parameters, represented by velocity magnitude fluctuation range (VMFR) and velocity direction fluctuation range (VDFR) for this status. A simulation model for helix TWT output performance with different velocity of electron beam is established and the results show that signal-to-noise ratio (SNR) decreases obviously when VMFR increases at VDFR=0° or VDFR increases at VMFR=0. However, SNR may become larger when VMFR and VDFR are simultaneously increased.

P1-2.26 / Higher harmonic of Super-radiant Smith-Purcell radiation

Zijie Xiong (University of Electronic Science and Technology of China, China), Min Hu (University of Electronic Science and Technology of China, China), Xiaoqiuyan Zhang (University of Electronic Science and Technology of China, China), Zhenghua Wu (University of Electronic Science and Technology of China, China), Pengfei HU (University of Electronic Science and Technology of China, China), Shaojie Chang (University of Electronic Science and Technology of China, China), Diwei Liu (University of Electronic Science and Technology of China, China), Shenggang Liu (University of Electronic Science and Technology of China, China)

Smith-Purcell radiation (SPR) is emitted when free electrons passing along the surface of the periodic grating. When electron bunch matches the surface wave in certain condition, a kind of enhanced coherent radiation can be produced from the interaction between electron bunch and the surface wave, referred to as the superradiant Smith-Purcell radiation (SSPR). Here, the high harmonics SSPR at Terahertz frequency and with stronger intensity is studied through theoretical calculation and electromagnetic simulation. The results show that the 2nd harmonic of Smith Purcell superradiation at 190GHz with 112mW energy and the 3rd Smith Purcell superradiation at 505GHz can be achieved by optimizing the structural parameters. The study of the high harmonics SSPR is of great significance to the development of THz radiation sources.

P1-2.27 / Investigation on 0.5THz Backward Wave Oscillator Based on Two-section Rectangular Gratings

Wenxin Liu (Chinese Academy of science, China) Qiangqing Ye (Chinese Academy of science, China), Xin Guo (Chinese Academy of science, China), Chao Zhao (Chinese Academy of science, China), Zhaochuan Zhang (Chinese Academy of science, China)

The 0.5THz backward wave oscillator, with Twosection rectangular gratings involving cylindrical electron beam, was developed. The length of the two-section backwardwave oscillator was determined by that of one section structure. The drift part linking the first section and second section, was located according to electron bunch. The output power of backward-wave oscillator is improved by introducing the floating part which can make the electron beam losing more energy and enhance the beam-wave interaction. The length of floating part was optimized by output power with particle-in-cell (PIC) simulations. When the length of floating part is 0.3mm, the maximum output power increases to 2.6W, comparing with that of one section structure (0.3W). Besides, the influences of conductivity, magnetic field, beam voltage and current on the output power are investigated through the CST simulation. The optimum results will be appeared in detailed abstract.

P1-2.28 / Research on Automatic Measurement Method of Saturation Characteristics of Broadband TWT

Dapeng Gong (University of Electronic Science and Technology of China, China), Tao Huang (University of Electronic Science and Technology of China, China), Jianqing Li (University of Electronic Science and Technology of China, China), Bin Li (University of Electronic Science and Technology of China, China)

The saturation characteristics is an important index of high power broadband traveling wave tubes. In this paper, an adaptive variable power stepping method is proposed to measure the saturation characteristics of broadband TWTs. In this method, we perform fast sweeping in the linear region and accurate sweeping in the saturation region respectively. Furthermore, the multi-level protection mechanism used in the measurement system can fully guarantee the safety and reliability of the measurement process. And this is of great significance in real measurement systems.

P1-2.29 / Research on the Test Method of Output Hot Standing Wave of High Power TWT

Xinai Liu (Chinese Academy of Sciences, China), FengZou (Chinese Academy of Sciences / University of Chinese Academy of Sciences, China), Gang Wang (Chinese Academy of Sciences, China), Guoxing Miao (Chinese Academy of Sciences, China), FangFang Song (Science and Technology on Reliability Physics and Application Technology of Electronic Component Laboratory, China)

In this paper, the measurement principle of TWT output hot standing wave is analyzed, and the test method of hot standing wave based on vector network analyzer (VNA) is put forward. The

feasibility of this method is preliminarily proved by analyzing and comparing the test results of the TWT output cold standing wave, and the output hot standing wave of L band TWT is measured in saturated and small signal states.

P1-2.30 / A Novel Method for Testing the Inner Temperature of Helix TWT under Operation using FBG

Jin Zhang (Southeast University, China), Jinyan Wang (Southeast University, China), Xiaohan Sun (Southeast University, China), Baoliang Hao (Beijing Vacuum Electronics Research Institute, China), Lei Zhang (Beijing Vacuum Electronics Research Institute, China), Yanmei Wang (Beijing Vacuum Electronics Research Institute, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China)

A novel method for testing the inner temperature of the helix TWT under operation using fiber Bragg grating (FBG) is proposed, in which the high-temperature FBG keeps in close contact with the support rod, and the gold-coated fiber stretching out is welded with the tube to keep vacuum tightness. In order to verify the feasibility of the method, simulation for the power performance of the helix TWT with different number of embedded fibers is performed, showing that using only one fiber could minimize the impacts on the operating performance. The helix TWT prototype with an embedded high-temperature FBG has been successfully manufactured, and the next step is to test the temperature inside the tube.

P1-2.31 / Design of a 1 kW output power Folded Waveguide TWT operating in ka-band

Antonino Mistretta (Leonardo S.p.A, Italy), Rosario Martorana (Leonardo S.p.A, Italy), Antonino Muratore (Teoresi S.p.A, Italy), Vincenzo Zito (Teoresi S.p.A, Italy), Romina Badalamenti (University of Palermo, Italy), Patrizia Livreri (University of Palermo, Italy)

A Ka-band Serpentine Folded Waveguide Travelling Wave Tube (TWT) has been designed. The imposed design parameters values in terms of high power, high load, wide bandwidth, low weight, along with a structure manufactured with planar technique or by means of a micro milling process, have been obtained. Small signal simulations have been carried out with an in-house software for interaction impedance evaluation. The commercial electromagnetic simulation code CST Suite has been used for dispersion diagram prediction. An optimization of the one-dimensional software, normally used for large-signal simulation in coupled cavity TWTs (“omputer Program for Analysis of Coupledcavity Travelling-wave-tube” by Cosmic) has been carried out, by reducing processing time and by achieving results found in a close agreement compared with the ones obtained by the Particle In Cell suite of CST. In this paper, the design theory of a 1 kW output power Ka-band Folded Waveguide TWT, will be explained and predicted data for the dispersion diagram and interaction impedance as well as “old test”results, in good agreement with each other, will be shown.

P1-2.32 / Thermal and Stress Analysis of the planar slow wave structure for Ka-band TWT

Hexin Wang (University of Electronic Science and Technology of China, China), Zhanliang Wang

(University of Electronic Science and Technology of China, China), Xinyi Li (University of Electronic Science and Technology of China, China), Tenglong He (University of Electronic Science and Technology of China, China), Duo Xu (University of Electronic Science and Technology of China, China), Tao Tang (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China)

A thermal simulation of a novel slow-wave structure (SWS) named planar dielectric-rods-support uniform metallic meander line (PDU-MML) was conducted in this paper, which mainly used in millimeter wave traveling wave tube (TWT). Due to the design idea of using two BN rods to support the metallic line, and coating copper film on metallic line, this new SWS could get a good heat dissipation capability. The simulation results show the temperature of the SWS could remain approximately nearly 100℃ when loading 300W microwave power. In addition, the stress analysis results show the mainly stress is concentrate on the interface between the BN rods and metallic line, which is nearly 20.4 MPa.

P1-2.33 / Microfabrication of A Conformal Microstrip Angular Log-periodic Meander Line TWT

Tenglong He (University of Electronic Science and Technology of China, China), Xinyi Li (University of Electronic Science and Technology of China, China), Hexin Wang (University of Electronic Science and Technology of China, China), Duo Xu (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Zhigang Lu (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China)

In this paper, a conformal microstrip angular logperiodic meander line (ALPML) TWT is designed and fabricated. This TWT can get the maximum output power 64W and gain 18dB at 36GHz. Ion beam etching technique is used to fabricate this conformal microstrip ALPML slow wave structure(SWS). The fabrication process of this conformal microstrip SWS is given.

P1-2.34 / Development of Q-band Space Traveling-Wave-Tubes

Bo Qu (Beijing Vacuum Electronics Research Institute, China), Xiaofeng Liang (Beijing Vacuum Electronics Research Institute, China), Chen Guo (Beijing Vacuum Electronics Research Institute, China), Yanhua Shang (Beijing Vacuum Electronics Research Institute, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China), Henghui Guo (Beijing Vacuum Electronics Research Institute, China)

Beijing Vacuum Electronics Research Institute (BVERI) has developed a series of Kaband space TWTs with saturation power of 12-100W and efficiency of 55-63% for data transmission and communication for both conduction and radiation cooling. Recently Q-band Space

traveling-wave-tubes (TWTs) with conduction-cooled and space qualified are developed which are capable of delivering over 45W saturated RF power with overall efficiency exceeding 45%. This paper gives the main technical characteristics of Q-band space TWTs' design, performances and qualification tests over 5.5GHz wideband in frequency range.

P1-2.35 / Design of an Ka-Band Multiple-beam Corrugated Waveguide TWT

Luanfeng Gao (University of Electronic Science and Technology of China, China), Yulu Hu (University of Electronic Science and Technology of China, China), Quan Hu (University of Electronic Science and Technology of China, China), Xiaofang Zhu (University of Electronic Science and Technology of China, China), Bin Li (University of Electronic Science and Technology of China, China)

A Ka-band multiple-beam corrugated waveguide traveling wave tube amplifier is designed and analyzed in this paper. The TWT uses corrugated waveguide with 50 periods as slow-wave structure and three electron beams to interact with the microwave traveling through the SWS. Simulation shows that the output power is greater than 600W from 31GHz to 36.5GHz with beam current of 0.2A and Voltage of 13.1kV. The maximum gain and electron efficiency are about 26 dB and 9.53% respectively. Comparing with double corrugated waveguide TWT, the multiple-beam corrugated waveguide TWT has higher output power, gain and efficiency. The structure is also applicable for the miniaturization of power amplifiers.

P1-2.36 / Design of Q Band Folded Waveguide Slow Wave Structures with Phase Velocity Taper Near Cutoff Region

Ruifeng Zhang (University of Electronic Science and Technology of China, China), Qi Wang (University of Electronic Science and Technology of China, China), Ping Han (University of Electronic Science and Technology of China, China), Zhixin Yang (University of Electronic Science and Technology of China, China), Zugen Guo (University of Electronic Science and Technology of China, China), Rujing Ji (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China)

A design of Q band folded waveguide(FWG) slow wave structure(SWS) with phase velocity taper is introduced in this paper. The novel design of slow wave structure is expanded from a conventional folded waveguide SWS. The SWS is designed to suppress oscillation and broaden bandwidth. Distinguished from the existing phase velocity tapering SWS, part of operating frequency is lower than the cutoff frequency of one section. The simulation results show that the output power is about 158W in a frequency range of 44-52GHz, with a 19-kV, 140-mA electron beam. The maximum output power and gain is up to 320W and 44dB, respectively. The electronic efficiency is over 6%.

P1-2.37 / Development of 50W V-Band space Travelling Wave Tube

Kangsong Tang (Chinese Academy of Sciences, China), Cha Gao (Chinese Academy of Sciences, China), Jtian Wang (Chinese Academy of Sciences, China), Feng Zhou (Chinese Academy of

Sciences / University of Chinese Academy of Sciences, China), Gxing Miao (Chinese Academy of Sciences, China), X bao Su (Chinese Academy of Sciences, China), Gang Wang (Chinese Academy of Sciences, China)

Institute of Electronics, Chinese Academy of Sciences(IECAS) has successfully developed a 50W V-Band space Travelling Wave Tube. This TWT has demonstrated more than 50W in 5GHz bandwidth, with efficiency more than 30%. The main design features and test results are describebed in this paper.

P1-2.38 / Optimization Design of Gridded Electron Gun Based on Multiphysics Simulation

Xiaofang Zhu (University of Electronic Science and Technology of China, China), Quan Hu (University of Electronic Science and Technology of China, China), Yulu Hu (University of Electronic Science and Technology, China), Bin Li (University of Electronic Science and Technology, China)

An optimization methodology is put forward for the design of gridded electron gun, which pays special attention to the spacings among cathode, shadow grid and control grid. The optimization is carried out on the basis of Microwave Tube Simulator Suite MTSS and multi-physics simulation software ANSYS. Using this optimization method, the electric performance of the designed gridded electron gun under working condition has minor changes compared to the simulation results. Using the designed spacings among cathode and the grids as mounting dimensions, the unexpected contact among cathode and the grids due to thermal deformation has less possibility to occur.

P1-2.39 / DC Analysis of Space Traveling Wave Tube

Nagaraju Atmakuru (CSIR-CEERI, India), Abhay Shankar (CSIR-CEERI, India), S.K. Ghosh (CSIR-CEERI, India)

The electron trajectory, from electron gun to collector through helix, of traveling wave tube (TWT) with magnetic field in DC condition is analyzed. The electron beam from cathode in the electron gun is confined by the PPM focusing structure and traversed helix in the RF section and collected in the collector. This paper presents complete DC simulation of a TWT and minimization of helix interception current by optimizing magnetic field as well as with secondary emission in collector using OPERA simulation software.

P1-2.40 / Design and Simulation of Electron Gun and Focusing System for High Power Space TWT

Abhay Shankar (CSIR-CEERI, India), Nagaraju Atmakuru (CSIR-CEERI, India), A.R. Choudhury (CSIR-CEERI, India), S.K. Ghosh (CSIR-CEERI, India)

A low Perveance Electron Gun with two anodes has been designed and simulated for high power Ku-band space traveling wave tube (TWT). A convergent pierce type electron gun is

designed using commercial softwares EGUN and CST-PS. The focusing system is designed using periodic permanent magnet (PPM) with confined flow technique in Magfld-EGUN and CST-PS.

P1-2.41 / Innovative Design of Helix Slow Wave Structure for Performance Improvement

Subhradeep Chakraborty (CSIR-CEERI, India), Pawan Pareek (CSIR-CEERI, India), Narashiman Purushothaman (CSIR-CEERI, India), Sanjay Kumar Ghosh (CSIR-CEERI, India)

In this paper, authors have presented design of a simple, novel helix SWS (HSWS) for flat power and gain frequency response with improved electronic efficiency in the X-band. To control the dispersion of the structure, the helix is supported with two different types of dielectric supports, namely, T and rectangular shaped and as a consequence flat power and gain have been achieved.

P1-2.42 / Design Study of Two-Plane Focusing Periodically Cusped Magnets for a 300 GHz Sheet Beam Traveling-Wave Tube

Wonjin Choi (Ulsan National Institute of Science and Technology, Korea) Ingeun Lee (Ulsan National Institute of Science and Technology, Korea), EunMi Choi (Ulsan National Institute of Science and Technology, Korea), Jinwoo Shin (Agency for Defence Development, Korea)

A sheet electron beam is an effective means to increase efficiency of traveling-wave tubes (TWTs). It is known that periodically cusped magnets (PCMs) can stably confine sheet electron beams. Also, PCMs have small volume, so the overall system can be portable. In this work, the magnetic field of PCMs are optimized for a 300 GHz sheet beam TWT. Simulations are done using Warp and CST Particle Studio. Numerical studies show that with peak magnetic field of 0.4 T and period of 3 mm, a sheet beam with size of 0.32 mm * 0.06 mm can stably propagate up to 30 mm.

P1-2.43 / Design of Slow Wave Structure for G-band TWT for High Data Rate Links

Rupa Basu (Lancaster University, UK), Laxma R. Billa (Lancaster University, UK), Jeevan M. Rao (Lancaster University, UK), Rosa Letizia (Lancaster University, UK), Claudio Paoloni (Lancaster University, UK)

The need of high data rate can be satisfied only by wide frequency bands in the millimetre wave region. This paper presents the design of a G-band (215 – 250 GHz) Traveling Wave Tube with 40 dB gain for wireless communications, based on the double corrugated waveguide. The structure of the TWT is based on a single section, instead of the typical configuration of two sections with a sever used at microwave frequency. This is possible due to the high losses at those frequency that permit a stable behaviour. This paper reports both cold and hot simulations.

P1-2.44 / Fabrication and Test of a W-band Three-Slot-Staggered-Ladder Coupled-Cavity TWT Circuit

Zhigang Lu (University of Electronic Science and Technology of China, China), Zhicheng Su (University of Electronic Science and Technology of China, China), Ruidong Wen (University of Electronic Science and Technology of China, China), Weihua Ge (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Tao Tang (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China)

In this paper, we report the fabrication and test of a W-band three-slot-staggered-ladder coupled-cavity TWT slow wave circuit. The process of fabrication involves coupled-cavity diaphragms, transition waveguides, and ceramic-window structures machining. Meanwhile the assembly is realized by the specially designed molds. The cold test was carried out using the Vector Network Analyzer (VNA). The measured S-parameters S_{11} is less than -10dB in the band of 92-99 GHz. The voltage stand wave ratio (VSWR) shows a good agreement with the simulation results. These results lay the foundation for the realization oftheW-bandthree-slot-staggered-ladder coupled-cavity TWT.

P1-2.45 / Transmission Characteristics of Double Staggered Grating Waveguide SWS: Simulation and Measurement

Weihua Ge (University of Electronic Science and Technology of China, China), Zhigang Lu (University of Electronic Science and Technology of China, China), Zhicheng Su (University of Electronic Science and Technology of China, China), Ruidong Wen (University of Electronic Science and Technology of China, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Tao Tang (University of Electronic Science and Technology of China, China), Huarong Gong (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China)

Transmission characteristics of a double staggered grating waveguide (DSGW) slow wave structure (SWS) with transition waveguides and input & output windows are presented. The DSGW-SWS was designed to operate at the band of 90-100GHz. The output power of over 1000 W at the bandwidth of 4GHz was obtained by PIC simulation. The current of sheet beam is 0.5 A. The single segment DSGW-SWS is used in the TWT for ensuring stable transmission of high beam-current. The DSGWSWS circuit was fabricated and experimentally tested for its cold behavior. The measured S-parameters (S_{11}) is less than -10 dB in the band of 94-100GHz. The Voltage Stand Wave Ratio (VSWR) shows a good agreement with the simulation results. The research results provide a perfect DSGW-SWS circuit for the successful development of W-band sheet beam TWT.

P1-2.46 / Investigation of a W-band 2π Band-edge Oscillator

Jun Cai (Beijing Vacuum Electronics Research Institute, China), Yinghua Du (Beijing Vacuum Electronics Research Institute, China), Xiaoqing Zhang (Beijing Vacuum Electronics Research Institute, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China)

To achieve full use of dispersion curve of periodic structures, the region near stop-band is studied, which is not treated as a useful region for traditional VEDs in the dispersion space of SWS. 2π band-edge of a folded waveguide SWS was firstly exploited instead of 4π. Based on beam-wave interaction simulation by PIC code, a PPM focused W-band 2π band-edge oscillator has been demonstrated successfully. The experimental prototype reaches maximum output power of 130W and the oscillator frequency of 96.7GHz with the voltage of 20kV and the current of 150mA in a compact length of 200㎜.

P1-2.47 / Design of W-Band Sheet Beam Electron Gun with PCM Focusing

Subham Chowdhury (CSIR-CEERI, India), A. K. Bandyopadhyay (CSIR-CEERI, India), Debasish Pal (CSIR-CEERI, India), Anirban Bera (CSIR-CEERI, India), Rajendra Sharma (CSIR-CEERI, India)

Sheet beam electron gun are need of the hour for compact terahertz Travelling Wave Tube (TWT) and EIK (Extended Interaction Klystron). In this paper, a planner sheet beam electron gun with Periodic Cusped Magnet (PCM) focusing is presented, and the structural parameters of this electron gun are optimized to get desired current. With proper optimization a sheet beam of cross section 1.68mm×0.2mm was achieved with 50mA current at a beam voltage of 18.4kV. Closed short periodic cusped magnetic system consisting of miniature permanent magnets and pole pieces have been used for transporting the sheet electron beam. The simulation results shows a PCM focused laminar sheet beam.

P1-2.48 / Design of a 50W 220GHz Traveling Wave Tube

Xingwang Bian (Beijing Vacuum Electronics Research Institute, China), Ye Tang (Beijing Vacuum Electronics Research Institute, China), Lin Zhang (Beijing Vacuum Electronics Research Institute, China), Ying Li (Beijing Vacuum Electronics Research Institute, China), Pan Pan (Beijing Vacuum Electronics Research Institute, China), Jun Cai (Beijing Vacuum Electronics Research Institute, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China)

A 50W 220GHz Traveling Wave Tube is designed based on folded waveguide (FWG) slow wave structure(SWS) with modified circular bends (MCBs) Pierce's type electron gun and periodical permanent magnet(PPM). The PIC results predict an average output power >60W with an instantaneous bandwidth of 5GHz when the voltage is 23kV and the beam current is 55mA.

P1-2.49 / Design of 0.22THz Folded-Waveguide Oscillator

Yi Jiang (China Academy of Engineering Physics, China), Wenqiang Lei (China Academy of Engineering Physics, China), Peng Hu (China Academy of Engineering Physics, China), Rui Song

(China Academy of Engineering Physics, China), Huang Yinhu (China Academy of Engineering Physics, China), Ma Guowu (China Academy of Engineering Physics, China), Hongbin Chen (China Academy of Engineering Physics, China), Xiao Jin (China Academy of Engineering Physics, China)

The folded-waveguide oscillator can get higher output power than the BWOs. This paper shows the design results of the 0.22THz folded-waveguide oscillator. The design has been conducted using analytic Pierce theory and timedomain simulations. The simulated results shows the maximum output power of the oscillator can reach 5W with the 18kV/50mA electron beam. The electric tunable bandwidth is about 1GHz in the range of 0.219THz ~ 0.22THz.

Poster 1

April 29 (Monday) / 15:10 ~ 16:30 / Capri room

Klystrons / MBKs

P1-3.1 / Design of a 4kW CW X-Band Broadband Klystron

Yuan Liang (Chinese Academy of Sciences, China), Honghong Gu (Chinese Academy of Sciences, China), Yaogen Ding (Chinese Academy of Sciences, China), Haibing Ding (Chinese Academy of Sciences, China), Bin Shen (Chinese Academy of Sciences, China), Caiying Wang (Chinese Academy of Sciences, China), Yueqing Liu (Chinese Academy of Sciences, China), Xiangjun Wang (Chinese Academy of Sciences, China), Wei Li (Chinese Academy of Sciences, China)

A continuous wave X-band klystron producing output power of 4 kW and bandwidth of over150MHz has been designed in Institute of Electronics, Chinese Academy of Sciences (IECAS). The design, manufacture, and test results have been reported in this paper. The results indicate that the performance of the tube satisfies the design requirement. The improved tube has a beam transmission rate over 97%, and operates very stably.

P1-3.2 / A 600kW C-Band Broadband Klystron with Wide Pulse-length

Xiu Liu (Beijing Vacuum Electronic Research Institute, China), Dongfengen Li (Beijing Vacuum Electronic Research Institute, China), Jun Zhou (Beijing Vacuum Electronic Research Institute, China), Kun Wang (Beijing Vacuum Electronic Research Institute, China), Jiajia Ouyang (Beijing Vacuum Electronic Research Institute, China), Haizhi Zhang (Beijing Vacuum Electronic Research Institute, China), Yongmeig Liu (Beijing Vacuum Electronic Research Institute, China) , Yueshuai Zhao (Beijing Vacuum Electronic Research Institute, China), Jitao Yang (Beijing Vacuum Electronic Research Institute, China), Sian Zhang (Beijing Vacuum Electronic Research Institute, China)

The putput section of the tube applied a 2-gap couple-output cavity techniques. The tube has a peak output power of 600kW, pulse-length of 200us, a instantaneous bandwith above of 220MHz, efficiency of 32%, gain of 43dB. The paper described the design issues, techniques features,computing simulation and test results.

P1-3.3 / Development of an X-band 650-kW Peak Output Power Klystron with a 100-MHz Instantaneous Bandwidth

Zhu Fang (Chinese Academy of Sciences, China), Liu Yueqing (Chinese Academy of Sciences, China), Li Yakun (Chinese Academy of Sciences, China), Zhang Zhenxia (Chinese Academy of Sciences, China), Li Xiuxia (Chinese Academy of Sciences, China), Zhou Guanli (Chinese Academy of Sciences, China), Wang Weilong (Chinese Academy of Sciences, China), Zhang Zhaochuan (Chinese Academy of Sciences, China), Luo Jirun (Chinese Academy of Sciences, China)

This paper presents the design considerations, the simulation, and the test results for an X-band klystron design with a 600-kW peak output power level, which was developed in 2018. Five klystrons were built and tested. Over 650-kW-peak-output power with a 100-MHz instantaneous bandwidth was measured at a 0.5% RF duty cycle (50-μs RF pulse-width and a 100-Hz repetition rate). The measured electron beam-to-RF conversion efficiency is 30%.

P1-3.4 / Simulation of high injection eficency of multi- beam diode for Ka-band relativstic klystron amplifier

Zhiwei Dang (University of Electronic Science and Technology of China / China Academy of Engineering Physics, China), Zhanliang Wang (University of Electronic Science and Technology of China, China), Hua Huang (China Academy of Engineering Physics, China), Shifeng Li (University of Electronic Science and Technology of China / China Academy of Engineering Physics, China), Yu Bai (China Academy of Engineering Physics, China), Jinjing Luo (University of Electronic Science and Technology of China, China), Yubin Gong (University of Electronic Science and Technology of China, China)

To generate annular multi-beam intense relativistic electron beams, a multi-beam diode of an Ka-band relativistic klystron amplifier is designed. The introduction efficiency and the quality of the electron beam are investigated by three-dimension particle in cell simulation. The simulation results show that the diode can generate 26 beams electron beams with high quality and introduction efficiency of about 99% by optimizing the key parameters of the multi-beam diode. The diode can be applied to multi-beam coaxial relativistic klystron amplifier with gigawatt-level output at Ka band.

P1-3.5 / Development of a C-Band High Effiency Klystron

Dmitriy A. Komarov (JSC “RPE “Toriy”, Russia), Evgeny P. Yakushkin (JSC “RPE “Toriy”, Russia), Yury N. Paramonov (JSC “RPE “Toriy”, Russia), Alexander N. Darmaev (JSC “RPE “Toriy”, Russia)

JSC Research and Production Corporation “Toriy” has designed and manufactured the KIU-273, a high peak power, high gain, C-band klystron. The klystron operates at 5712 MHz, with 3.4 MW peak output power, 25kW average output power, and gain of 55 dB. Experimental date is presented.

P1-3.6 / DESIGN OF CEPC HIGH EFFICIENCY MULTIBEAM KLYSTRON

Shengchang Wang (Chines academy of science, China), Shigeki Fukuda (High Energy Accelerator Research Organization, Japan), Zusheng Zhou (Chines academy of science, China), Un-Nisa Zaib (Chines academy of science, China), Zhijun Lu (Chines academy of science, China), Shilun Pei (Chines academy of science, China), Dong Dong (Chines academy of science, China), Ouzheng Xiao (Chines academy of science, China), Guoxi Pei (Chines academy of science, China)

This paper presents the design and simulation of CEPC 650MHz/800kW CW multibeam klystron. To get high efficiency, single beam perveance is chosen to be as low as 0.2μP. On the other

hand, beam voltage is 54kV which could be considered as a safe vale in CW operation. Three dimensional PIC simulations of CEPC MBK predict an efficiency of 80%.

Poster 1

April 29 (Monday) / 15:10 ~ 16:30 / Capri room

EIKs / EIOs / Oscillators

P1-4.1 / Response Analysis of RF System of a W-band Extended Interacting Oscillator

Zhaowei Qu (Chinese Academy of Sciences, China), Zhiqiang Zhang (Chinese Academy of Sciences, China) Yaogen Ding (Chinese Academy of Sciences, China), Shuzhong Wang AND(Chinese Academy of Sciences, China), Qingsheng Li (Chinese Academy of Sciences, China)

This paper introduces a method of response analysis of RF circuit system for the design of a W-band Extended Interacting Oscillator (EIO). The RF system design adopts 2π operating mode, trapezoidal slow wave structure with dual coupling slots. With regard to the frequency response of the output circuit, it can be analyzed and compared by CST software and the vector net test. The electric field distribution of three frequency responses is observed by simulation. Among them, the groove can be confirmed by short circuit, and the other clutter needs to be confirmed by PIC simulation to verify the reliability of the design scheme.

P1-4.2 / Operation Status of 80 MW Klystron and 200 MW Modulator for PAL-XFEL

Soung-Soo Park (Pohang Accelerator Laboratory, Korea), Yong Jung Park (Pohang Accelerator Laboratory, Korea), Sang Hee Kim (Pohang Accelerator Laboratory, Korea), Chang-Ki Min (Pohang Accelerator Laboratory, Korea), Kwang-Hoon Kim (Pohang Accelerator Laboratory, Korea), Heung-Sik Kang (Pohang Accelerator Laboratory, Korea)

The construction of Pohang Accelerator Laboratory X-ray Free Electron Laser(PAL-XFEL) was completed by the end of 2015. Acceleration modules used in the 4th generation electronic acceleration are 51 modules including Hard X-ray and Soft X-ray. Among the high power pulse power devices used as energy source for accelerating electrons in the 4th generation linear accelerator, the beam is being supplied to the user in 30 Hz, 4uS, SLED tune mode of the 49 sets module installed in the hard X-ray. The PAL-XFEL needs a highly stable electron beam. The very stable beam voltage of a klystron-modulator is essential to provide the stable acceleration field for an electron beam. Thus, the modulator system for the XFEL requires less than 50 ppm beam voltage stability. To get this high stability on the modulator system, the inverter type HVPS is a pivot component. And the modulator needs lower noise and more smart system. The commissioning began in April 2016, and the lasing of the hard X-ray FEL was achieved on end of 2016. Beginning to provide users with beams from 2017, we will present the operating status of the Klystron-modulator when providing beams to users in 2018.

P1-4.3 / Design of an Electron Optics System for L-Band Klystron

Xiudong Yang (Chinese Academy of Sciences, China), Rui Zhang (Chinese Academy of Sciences,

China), Zhiqiang Zhang (Chinese Academy of Sciences, China)

This paper describe the design of an electron optics system for L-band klystron with a power of 20 MW. When the cathode voltage and the current are 223 kV and 172 A, respectively, the beam radius is 10 mm, and the transmission distance is more than 1000 mm. In the solenoid focusing system, two compensative coils are arranged outside the collector to increase the magnetic field near the output cavity. The electron beam transfers stably with a radius of maximum radius of 12 mm and a minimum radius of 9 mm.

P1-4.4 / Design of an RF Circuit for L-Band 25MW Klystron

Rui Zhang (Chinese Academy of Sciences, China), Xiudong Yang (Chinese Academy of Sciences, China), Zhiqiang Zhang (Chinese Academy of Sciences, China)

This paper describe the design of an RF circuit for L-band klystron with an output power of 25 MW. When the cathode voltage and the current are 240 kV and 200 A, respectively, the gain of the klystron is 61 dB and the efficiency is more than 52%.

P1-4.5 / Design of a RF interaction system for a Ka-band EIK

Yihao Song (University of Chinese Academy of Sciences, China), Haibing Ding (Chinese Academy of Sciences, China), Ke Tang (Chinese Academy of Sciences, China), Ren Xiao (Chinese Academy of Sciences, China)

In this paper, a RF interaction system used in a Ka-band CW extended interaction klystron (EIK) is introduced. The circuit of this system is analyzed and optimized by using Computer Simulation Technology (CST). A sample tube has been fabricated in the summer of 2018. Working at frequency point 35.07GHz, with the 8.2kV cathode voltage and the 0.36A cathode current, the tube reaches 440W CW output power, and its 3dB bandwidth is over 120MHz. By adjusting the curcuit of output cavity, Particle-in-Cell (PIC) simulation results show that the system is capable of achieving 27.6% electronic efficiency at 35GHz, CW output power reaching about 1250W.

P1-4.6 / Modeling of A Converging Hollow Beam Electron Optic System for a Ka-Band EIK

Tongli Ma (Chinese Academy of Sciences / University of Chinese Academy of Sciences, China), Ding Zhao (Chinese Academy of Sciences, China), Zhaochuan Zhang (Chinese Academy of Sciences, China)

In this paper, the design of a 25 kV, 2.5 A hollow beam electron gun for a Ka-band extended interaction klystron has been analyzed in detail. The hollow beam electron gun has two control focus electrodes, which can switch on/off the device quickly. The influence about the geometry parameters on perveance, beam waist, beam throw and beam laminearity are studied. The simulation result shows a hollow beam with 8% outer envelope ripple amplitude, 100 transmission ratio, 122.8 area compression ratio can propagates 49.4mm (from the cathode to

the entrance of collector) with good laminarity under a uniform magnetic flux density of 0.7 T.

P1-4.7 / Investigation on a Broadband 220GHz Extended Interaction Klystron

Wang Zicheng (Chinese Academy of Sciences, China), Qu Zhaowei (Chinese Academy of Sciences, China), Li Lianbing (Chinese Academy of Sciences / University of Chinese Academy of Sciences, China), Shang Xinwen (Chinese Academy of Sciences, China), Cao Linlin (Chinese Academy of Sciences / University of Chinese Academy of Sciences, China), Tang Bojun (IChinese Academy of Sciences, China), Xiao Liu (Chinese Academy of Sciences, China)

An extended interaction klystron , which is composed of an input cavity and an output cavity both based on 8 periods of staggered double rectangular waveguide structure (SDRWS) and an intermediate cavity based on 6 periods of SDRWS, is calculated in details on computer. After calculating S_{11} of the input cavity and an output cavity and the eigenmodes of the intermediate cavity, the structural parameters of the input cavity and an output cavity and the intermediate cavity are determined, then PIC simulation is done to predict the EIK's performance, the results show that the EIK has an 1 GHz-wide of 3 dB band which cover 219.5-220.5GHz, a 456 W of maximum power and a 40.06 dB of maximum gain. Furthermore, stagger tuning by adjusting the structural parameter a of the intermediate cavity is performed to analyse how a affects the EIK's performances, and the results show that the 3 dB band of the EIK mainly depends on the passband of the input cavity and output cavity, but also depends on the resonant frequency of the intermediate cavity in some cases. When the resonant frequency of the intermediate cavity is located at the lower or higher ends of the passband of the input cavity and an output cavity, the 3 dB band of the EIK may be extended to certain extent. Particularly, when the resonant frequency of the intermediate cavity is located at or beyond the higher ends of the passband of the input cavity and an output cavity, it is verified that the EIK has steady output signal featuring with pure spectrum and has flat gains over the 3 dB band. The final results of the stagger tuning show that , when the structural parameter a of the intermediate cavity is 0.747 mm, the EIK reaches almost the optimum performances, with an 1 GHz-wide of 3 dB band which cover 219.5-220.7GHz, a 630 W of maximum power companied with a 11.3% of efficiency, and a 47 dB of maximum gain.

P1-4.8 / Primary Study On High Frequency Structure of 38GHz Extended Interaction Oscillator

Jielong Li (University of Electronic Science and Technology of China, China), Zhenhua Wu (University of Electronic Science and Technology of China, China), Chuanhong Xiao (University of Electronic Science and Technology of China, China), Jie Qing (University of Electronic Science and Technology of China, China), Bo Wang (University of Electronic Science and Technology of China, China), Min Hu (University of Electronic Science and Technology of China, China), Renbin Zhong(University of Electronic Science and Technology of China, China), Shenggang Liu (University of Electronic Science and Technology of China, China)

In this article, a cavity with a frequency of 38GHz is designed. Through numerical calculation and computer simulation, TM_{31} mode, the dispersion curve, quality factor and S_{11} parameter of a high frequency structure of 38GHz extended interaction oscillator are studied. S_{11} parameter is

calculated to find optimum output window size for cold-test experiment. And the results of particle simulation is also shown in this article. Compared with the results of cold cavity, the results of particle simulation are consistent. This research is of great significance for the development of millimeter wave vacuum devices.

P1-4.9 / Double Multi-Gap Output Cavity for Low Voltage Ultra-Compact W-Band Klystron

Yuan Zheng (University of California, U.S.A), Neville C. Luhmann Jr. (University of California, U.S.A), Diana Gamzina (SLAC National Acceleration Laboratory, U.S.A), Ann Sy (SLAC National Acceleration Laboratory, U.S.A), Brandon R. Weatherford (SLAC National Acceleration Laboratory, U.S.A)

A W-band, ultra-compact continuous wave sheet beam klystron aiming to produce 2 kW power is being developed to demonstrate compactness and high efficiency. The design utilizes a comparatively low voltage electron beam benefiting the device size and extending its application space; however, the lower operation voltage significantly affects the beam-wave interaction efficiency. Two single port multi-gap output cavities have been employed to achieve a higher beam interaction efficiency without introducing additional competing modes. By applying the new design, the simulation output power has been improved to 1.7 kW from 1.0 kW and the interaction efficiency increased by 2.1%.

P1-4.10 / Thermal Analysis of Electron Gun for the Sheet Beam Extended Interaction Oscillator

Lingshan Rui (University of Electronic Science and Technology of China, China), Jianxun Wang (University of Electronic Science and Technology of China, China), Xiaoxiao Li (University of Electronic Science and Technology of China, China), Zeng Liu (University of Electronic Science and Technology of China, China), Wei Jiang (University of Electronic Science and Technology of China, China), Yulu Hu (University of Electronic Science and Technology of China, China), Yong Luo (University of Electronic Science and Technology of China, China)

An novel heater structure capable of providing higher heating efficiency is designed. A method is proposed to equate the thermal resistance that occurs during the actual assembly process. The thermal and structural analysis of the sheet beam gun are completed using the finite element code ANSYS. The new structure reduces heating power by 50% (31.6 W to 15.9 W) at a cathode temperature of 1100°C and also shows better performance in thermal deformation than the previous one.

P1-4.11 / A High Order Mode sheet-beam Extended Interaction Oscillator at Ka-band

Jiaxin Gong (University of Electronic Science and Technology of China, China), Liangjie Bi (University of Electronic Science and Technology of China, China), Yong Yin (University of Electronic Science and Technology of China, China), Hailong Li (University of Electronic Science and Technology of China, China), Bin Wang (University of Electronic Science and Technology of China, China), Lin Meng (University of Electronic Science and Technology of China, China)

In this paper, a Ka-band sheet-beam extended interaction oscillator (EIO) operating at TM_{31} is designed, which combines the advantages of the sheet beam and higher order mode to generate high power radiation in millimeter wave. The field distribution and output power are analyzed to show the potential of the TM_{31} mode associated with the sheet beam technology in obtaining high power. The characteristic impedance is optimized to make an effective beam-wave interaction. To demonstrate its capability, a rectangular sheet beam with a width-to-height of 8mm×1mm is injected in the EIO to simulate the beam-wave interaction. Simulation results show that the oscillator generates a millimeter-wave power of 81.6 kW with a beam current of 12 A, a beam voltage of 30 kV. The frequency of the output millimeter wave is 35.25 GHz.

P1-4.12 / Experimental Study of a 6 kW W-band PCM Focused Sheet Beam EIO

Jianxun Wang (University of Electronic Science and Technology of China, China), Xiaoxiao Li (University of Electronic Science and Technology of China, China), Lingshan Rui (University of Electronic Science and Technology of China, China), Zeng Liu (University of Electronic Science and Technology of China, China), Guo Liu (University of Electronic Science and Technology of China, China), Wei Jiang (University of Electronic Science and Technology of China, China), Zewei Wu (University of Electronic Science and Technology of China, China), Yulu Hu (University of Electronic Science and Technology of China, China), Yong Luo (University of Electronic Science and Technology of China, China)

The study and experimental studies of a 6 kW W-band PCM focused high power sheet beam extended interaction oscillator are firstly reported. The initial hot test results show a 6 kW maximum output peak power with a 47.2 kV and 2.1 A beam. An average power of 1.2 kW is obtained with a 20% working duty. The stable operation shows a much higher potential average power capability. A new designed PCM magnet is applied in the beam focusing. It presents a 99% static beam transmission and 94.4% beam transmission with saturated RF interaction. The overall dimensions and weight of the SBEIO are 400X100X60 mm and 7 kg.

P1-4.13 / A High Power W-band Extended Interaction Klystron

Ying Wei (Beijing Vacuum Electronics Research Institute, China), Dongfeng Li (Beijing Vacuum Electronics Research Institute, China), Jun Zhou (Beijing Vacuum Electronics Research Institute, China), Jitao Yang (Beijing Vacuum Electronics Research Institute, China), Liang Yin (Beijing Vacuum Electronics Research Institute, China), Jiajia Ouyang (Beijing Vacuum Electronics Research Institute, China)

This paper briefly introduces the design of a W-band extended Interaction Klystron, and gives the test results. By now, with an electron beam of 17 kV and 0.76 A, the EIK has achieved a peak output power of 1.5kW, 3dB bandwidth of 1GHz, and gain of 40dB.

P1-4.14 / Third-Harmonic Operating Extended Interaction Oscillator

Ping Zhang (University of Electronic Science and Technology of China, China), Ying Yong (University of Electronic Science and Technology of China, China), Xiaosong Wang (University of

Electronic Science and Technology of China, China), Liangjie Bi (University of Electronic Science and Technology of China, China), Bin Wang (University of Electronic Science and Technology of China, China), Lin Meng (University of Electronic Science and Technology of China, China)

A promising version of THz extended interaction oscillator (EIO) is developed to operate in high harmonic, which permits a breakthrough in the frequency limits of conventional version supported by fundamental mode. The specific design and mode analysis in the ladder-type RF circuit is carried out to excite the third harmonic on the base of the effective modulation with the fundamental mode. The dispersion characteristic of the RF circuit is analyzed to discuss the feasibility of the operation in the third harmonic. To demonstrate the circuit capability, the beam-wave interaction with respect to the fundamental mode and third harmonic is studied by using 3-D Particle-in-cell simulation technology. The third harmonic radiation from a low-frequency RF circuit is achieved by using this method and the start current still maintain the normal level in the low-frequency RF circuit. This provides a novel method for pushing the development of the THz radiation sources.

P1-4.15 / Design and Particle-in-cell Simulation of a Ka-band Extended Interaction Klystron with Five Three-gap Coupled Cavities

Haiyu Zhang (Chinese Academy of Sciences, China), Jirun Luo (Chinese Academy of Sciences, China)

A Ka-band high gain extended interaction klystron (EIK) with five Hughes-type three-gap coupled cavities is designed and 3D particle-in-cell (PIC) simulation by CST code is performed to calculate the performances of the EIK in this abstract. Under the beam voltage of 14 kV and the current of 1 A, the RF output power is 2.15 kW at the operating frequency of 35 GHz. The corresponding gain and efficiency are 43.78 dB and 15.36%, respectively, and the 3 dB bandwidth reaches 248 MHz.

P1-4.16 / Beam-matching design for suppressing beam losses in high-power klystrons

Jihyun Hwang (POSTECH, Korea), Sung-Ju Park (Pohang Accelerator Laboratory, Korea), Yong-Jeong Park (Pohang Accelerator Laboratory, Korea), Won Namkung (Pohang Accelerator Laboratory, Korea), Dongho Yu (VIZTRO NEXTECH Co., Ltd, Korea), Daehee Kim (VIZTRO NEXTECH Co., Ltd, Korea), Sungsu Cha (VIZTRO NEXTECH Co., Ltd, Korea)

In order to suppress beam losses and radiations in high-power klystrons, the electron beam should be desinged to have the scalloping (i.e., the radial oscillation of beam envelope) as small as possible. This is done by matching the focusing field profile with beam trajectories (which are usually convergent). In this article, we report on the beam-matching simulations using a newly developed matching procedure with various beam radii and design solenoid magnets of S-band klystrons at Pohang Accelerator Laboratory (PAL).

P1-4.17 / A new type of the small-sized double-gap multi-beam klystron resonator based on Greek-cross fractal geometry

Vladislav Tsarev (University of Saratov, Russia), Alexey Miroshnichenko (University of Saratov, Russia), Natalia Akafyeva (University of Saratov, Russia)

The paper presents results of modeling parameters of the compact double-gap resonator for 19-beam klystron type devices with a resonant fractal structure of the Greek-cross type for "0-th", "1-st" and "2-nd" iteration. Resonance elements made on the central electrodes of a symmetrical high-Q strip line suspended on a diamond dielectric substrate. The resonator has two fundamental modes of oscillation: in-phase and anti-phase. The main mode of the oscillations of the resonator is anti-phase. It corresponds to the X-range of frequencies used in satellite communications. The first higher oscillation mode (in-phase) corresponds to the Ku-band. The optimal parameters of the interaction process are found.

P1-4.18 / Design of a 0.35 THz Extended Interaction Oscillator Based on Pseudospark-Sourced Sheet Electron Beam

Jie Xie (University of Electronic Science & Technology of China, China / University of Strathclyde, UK), Adian W. Corss (University of Strathclyde, UK), Wenlong He (Shenzhen University, China), Huabi Yin (University of Strathclyde, UK), Liang Zhang (University of Strathclyde, UK), Alan D. R. Phelps (University of Strathclyde, UK)

A design of a 0.35 THz extended interaction oscillator (EIO) driven by pseudospark-sourced sheet electron beam is presented. PIC-3D simulations reveal that an output power of about 1.5 kW can be achieved when driven by a sheet electron beam with a voltage of 35 kV and a current density of 0.5 x 10^8 A/m^2 at 352 GHz.

P1-4.19 / A Periodic Cusped Magnetic – Quad Magnetic Focusing System for Low Voltage Ultra-Compact W-Band Klystron

Yuan Zheng (University of California, U.S.A), Neville C. Luhmann, Jr. (University of California, U.S.A), Diana Gamzina (SLAC National Acceleration Laboratory, U.S.A), Joe Olszewski (SLAC National Acceleration Laboratory, U.S.A), Ann Sy (SLAC National Acceleration Laboratory, U.S.A), Weatherford Brandon R. (SLAC National Acceleration Laboratory, U.S.A)

A Periodic Cusped Magnet (PCM) - Tunable Quadrupolar Magnet (TQM) is proposed to focus the sheet electron beam of a low voltage W-Band, ultra-compact continuous wave sheet beam klystron (LUWK). The design utilizes a PCM to prevent the vertical beam spreading, and a TQM to control transverse beam spreading the force. Employing the PCM-TQM not only benefits the compact size of the LUWK, but it also mitigates the Diocotron instability of the sheet beam. Using the PCM-QM focusing system, the MAGIC-3D simulations show that an elliptical sheet beam with transverse size 6.0 mm x 0.5 mm can achieve a 99% cold beam transmission, and a 97% hot beam transmission through a 140 mm beam tunnel.

Poster 1

April 29 (Monday) / 15:10 ~ 16:30 / Capri room

Cathodes

P1-5.1 / Thermionic Emission Mechanism of the Novel Y_2O_3-Gd_2O_3-HfO_2 Impregnated W base Direct-heated Cathode

Shikai Qi (Jiujiang University, China), Mingwei Hu (Xidian University, China), Wei Zeng (Jiujiang University, China)

In order to enhance the emission current, reduce the operating temperature and prolong the lifetime of the pure W filament cathode for application in high-ower (i.e., more than 10KW) continuous wave magnetron tube, a novel Y_2O_3-Gd_2O_3-HfO_2 impregnated W base direct-heated cathode (YGd-Hf-O impregnated cathode) has been developed. In this abstract, the thermionic emission mechanism of the Y-Gd-Hf-O impregnated cathode has been researched by SEM, EDS and AES.

P1-5.2 / Study on inhibition Of the M-Type Cathode edge emission in the high frequency vacuum electronic devices

Hui Wang (Beijing Vacuum Electronics Research Institute, China), Wensheng Shao (Beijing Vacuum Electronics Research Institute, China), Gaoyu Juan (Beijing Vacuum Electronics Research Institute, China), Pengyun Yang (Beijing Vacuum Electronics Research Institute, China), Ke Zhang (Beijing Vacuum Electronics Research Institute, China)

The ion beam film deposition technique has been introduced to inhibit the emission of the M-Type cathode edge in our research, by which the surface of the cathode is coated with a metal membrane, such as hafnium(Hf), zirconium(Zr) and tantalum (Ta). Below 900ºC, the effect of the inhibit membrane is all well, which the emission current density decreased to 0.3A/cm². With the best inhibitory of hafnium, it has been evidenced by XPS and XRD analysis that the inhibition mechanism of Hf film cathode, which was investigated by the interaction between barium and hafnium.

P1-5.3 / Dispenser M-type cathodes with alloy films made on the basis of osmium or rhenium for application in long life microwave devices

A.P. Makarov (JSC “RPC”Istok” named after Shokin, Russia), E.M. Zemchikhin (JSC “RPC”Istok” named after Shokin, Russia)

Results of investigation of emission properties, life time, elemental composition of the surface and change of these properties during the life of dispenser cathodes covered with films on basis of osmium and rhenium are presented. Dispenser cathodes covered with films (Re-Hf and Os-Hf)

can be used as effective sources of thermo and secondary electrons.

P1-5.4 / Pressed metal-alloy palladium-barium cathode

O.V. Polivnikova (FSUE "RPC "Istok", Fryazino, Moscow reg., Russia), I.P Li (OJSC "Pluton", Russia)

In filament-free magnetrons which are activated by electron emission from field-radiating cathodes its necessary level is provided by adsorption of active metal barium coming from the main palladium-barium cathode. The developed pressed palladium-barium cathode allows to change barium evaporation speed due to change of its porosity and hence barium Knudsen flow. It will lead to emission level control of field radiating cathodes.

P1-5.5 / HfC thermal field emitter: a brief study

Victor Katsap (NuFlare Technology America, Inc., USA)

In thermal field emission (TFE) technology, Schottky ZrO/W emitters reign supreme. We have tested a potential contender, HfC TFE.

P1-5.6 / A Study on the thermal emission properties of Y-Gd-Hf-O refractory rare earth oxides cathode

Xiqoqian Chen (Institute of Electronics, Chinese Academy of Sciences, China), Xiaoxia Wang (Institute of Electronics, Chinese Academy of Sciences, China), Zhaochuan Zhang (Institute of Electronics, Chinese Academy of Sciences, China), Yun Li (Institute of Electronics, Chinese Academy of Sciences, China), Qinglan Zhao (Institute of Electronics, Chinese Academy of Sciences, China), Qi Zhang (Institute of Electronics, Chinese Academy of Sciences, China)

Y_2O_3-Gd_2O_3-HfO_2 refractory rare earth oxide direct-heating cathode has the advantages of simple preparation process, high thermal emission current density, large secondary electron emission coefficient and long life, and has a good application potential in high-power continuous wave magnetrons. In order to further improve the thermal emission properties of the Y_2O_3-Gd_2O_3-HfO_2 cathode, the mitter active substance of the cathode was doped with different ratios of Sc_2O_3. The results show that the doping of Sc_2O_3 can effectively improve the thermal emission current density of Y_2O_3-Gd_2O_3-HfO_2 cathode. Among them, the thermal emission current density of Y_2O_3-Gd_2O_3-HfO_2 cathode doped with 10wt% Sc_2O_3 reached 5.3A/cm^2 at 1500°C, which was 35.5% higher than that of undoped.

P1-5.7 / Femtosecond laser direct writing fabricate single crystal LaB_6 FEA and their field emission

Zhang xin (Beijing University of Technology, China), Hongliang Liu (Beijing University of Technology, China), Zhang Wei (AVIC Beijing Research Institute of Aviation Engineering, China), Zhang Jiuxing (Beijing University of Technology / Hefei University of Technology, China)

In theory, single crystal LaB_6 as field emission materials have best comprehensive properties. At present, the single crystal LaB_6 field-emission tip arrays (FEA) is difficult to be effective produced using conventional micro machining method such as ion beam etching, electron beam lithography, chemical etching and mechanical micro machining due to its stable physicochemical properties, hard and brittleness properties, which limited the field emission application of single crystal LaB_6. The appearance of femtosecond (fs) laser technology and the application of stable and reliable commercial femtosecond laser equipment provide an effective tool for high quality processing of materials. Hence, it is very meaningful to reliability-accurate fabricate single crystal LaB_6 FEA by the femtosecond laser method and investigate their field emission. In this work, the femtosecond laser direct writing method been used to fabricate the single crystal LaB_6 FEA. The morphologies, structure phase as well as the field emission of the single crystal LaB_6 FEA are systematically studied. The nanostructures on the surface of tips with LaB_6 phase were formed, resulting in favor of improving field emission, particularly for samples with the nano-hill shaped bulges having the size of about 100nm. The produced single crystal LaB_6 FEA have uniform structure and a controllable curvature radius of about 0.5-3.0 μm. The FEA with a curvature radius of about 0.5 μm as field emitters have the best field emission performance, which the turn-on electric fields are as low as 2.2 with an emission current of 1.0 A/cm^2 at 8.0 V/μm and the emission current exhibits high stability. These indicating the processed LaB_6 FEA have a good prospect applied in vacuum microelectronic devices and the simple femtosecond laser direct writing method could lead to an approach for the development of electron sources.

P1-5.8 / Electron-Optical System with Planar-Arranged Coarse-Structured Field Emission Cathodes

Sergey Morev (JSC “RPE “Toriy”, Russia), Alexander Darmaev (JSC “RPE “Toriy”, Russia), Dmitry Komarov (JSC “RPE “Toriy”, Russia), Kirill Kuzmich (JSC “RPE “Toriy”, Russia), Eduard Muraviev (JSC “RPE “Toriy”, Russia), Sergey Maslennikov (National Research Nuclear University “MEPhI”, Russia), Victor Sablin (JSC “RPE “Toriy”, Russia)

The experimental study results of the coarse-structured field emission cathode cell with a tungsten emitter intended for millimeter range O-type device are presented. The propagation of an electron beam formed by a single-row nine-beam field emission cathode array in long rectangular (0.9 mm x 8.0 mm) beam channel is shown.

P1-5.9 / Measurement Method of the Distribution of Field Emission Current

Dmitry Ozol (Moscow Institute of Physics and Technology, Russia), Alexander Eliseevl (Moscow Institute of Physics and Technology, Russia), Maksim Garkushal (Moscow Institute of Physics and Technology, Russia), Anton Pavlenkol (Moscow Institute of Physics and Technology, Russia)

The density of field emission current is distributed over the anode in substantially nonhomogeneous way. A method that allows one to evaluate the degree of the nonhomogenuity and measure the current density using color variation cathode-ray-tube phosphors is proposed.

P1-5.10 / Simulation Study of Compact Carbon Nanotube Cold-cathode Oscillator

Xiaotao Xu (University of Electronic Science and Technology of China, China), Yifan Zu (University of Electronic Science and Technology of China, China), Xusong Yuan (University of Electronic Science and Technology of China, China), Qingyun Chen (University of Electronic Science and Technology of China, China), Bin Wang (University of Electronic Science and Technology of China, China), Hailong Li (University of Electronic Science and Technology of China, China), Yang Yan (University of Electronic Science and Technology of China, China)

A compact carbon nanotube cold-cathode oscillator operating at terahertz band is designed by PIC simulation software in this paper. The cathode part is integrated with the high frequency structure. The field emission beam of the cold cathode is modulated by the high frequency field in the high frequency structure directly. The simulation results show that a peak output power of 3.4W is obtained at 140GHz, and the emission current modulation depth is 7.7% when the surface electric field strength of the cathode is 12V/μm.

P1-5.11 / Semiconductor-Free Field-Emission Nanoelectronics: Application in Air-Channel Transistors

Shruti Nirantar (RMIT University, Australia), Taimur Ahmed (RMIT University, Australia), Guanghui Ren (RMIT University, Australia), Philipp Gutruf (University of Arizona, USA) Chenglong Xu (RMIT University, Australia), Madhu Bhaskaran (RMIT University, Australia), Sumeet Walia (RMIT University, Australia), Sharath Sriram (RMIT University, Australia)

We introduce a nano-scale, metal-based, field emission air channel transistor. Comparative analysis of tungsten, gold, and platinum based devices is presented. Devices are fabricated with electron beam lithography, achieving channel lengths less than 35 nm. With this small channel length, vacuum-like carrier transport is possible in air under room temperature and pressure. Source and drain electrodes have planar, symmetric, and tapered-sharp geometry. Due to this, devices operate in bi-direction with voltages <2 V and current in nA range. The presented work enables a technology where metal-based switchable nanoelectronics can be created on any dielectric surface with low energy requirements.

P1-5.12 / Study on Electron Beam Bunching in a Gigahertz Oscillating Electric-Field Direct-Driven Cold-Cathode Electron Gun

Yang Xing (Sun Yat-Sen University, China), Yu Zhang (Sun Yat-Sen University, China), Ningsheng Xu (Sun Yat-Sen University, China), Yanlin Ke (Sun Yat-Sen University, China), Baohong Li (Sun Yat-Sen University, China), Shaozhi Deng (Sun Yat-Sen University, China)

The electron beam of an oscillating electric-field direct-driven cold-cathode electron gun in resonant structure is studied. Such electron gun is capable of providing modulated electron beam and has potential for novel vacuum electronic devices applications. However, the problem of electron beam divergence in the electron gun needs to be solved. By designing the position of cold-cathode and improving the electric field distribution on the cold-cathode surface, the

divergence of the electron beam is reduced and the transmission ratio of the electron gun is effectively improved from 75.90% to 94.78%. Further, by applying an axial magnetic field, the transmission ratio is optimized to 97.73%. The method for electron beam bunching optimization is simply and effective, it could find applications in microwave and terahertz vacuum electronic devices.

P1-5.13 / Development of microfabricated scandate dispenser cathode and electron gun for terahertz vacuum electron devices

Seong Lee (Agency for Defense Development, Korea), Jinwoo Shin (Agency for Defense Development, Korea), Joonho So (Agency for Defense Development, Korea), Jung hyo Park (Agency for Defense Development, Korea), Changgu Kim (Agency for Defense Development, Korea)

Scandate dispenser cathode with hundreds of ampere per square centimeter has been developed using metal injection molding (MIM) technique for terahertz vacuum electron devices. We have investigated scandate thermionic cathode surface by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) before surface treatment. And then, scandate cathode was fabricated with 1 mm diameter. The performance was verified by beam transmission test after assembling electron gun using microfabricated scandate cathode. The beam transmission rate was 99.8% for 0.5 mm radius drift tube with 0.8 T magnetic field condition.

P1-5.14 / Numerical Analysis of Inter-Electrode Capacitance of Vacuum Micro-Electronics Devices

S Manna (The University of Burdwan, India), A K Singh (CSIR-CEERI, India), R K Sharma (CSIR-CEERI, India), Ranjan Barik (CSIR-CEERI, India)

In this paper, calculation of inter-electrode capacitance per unit length of vacuum micro-electronics devices is presented using finite difference method (FDM). A comparison of the analytical values with the simulation data of the same structure is also presented in this paper. The analytical results closely match with simulation results.

P1-5.15 / Defect-enhanced field electron emission from WO_{3-x} nanowires

Zufang Lin (Sun Yat-sen University, China), Paibin Xie (Sun Yat-sen University, China), Jun Chen (Sun Yat-sen University, China)

Field emission properties of WO_{3-x} nanowires prepared on glass substrate were studied. Current up to 3 mA were achieved from an effective area of 0.25 cm^2, corresponding to a current density of 12 mA/cm^2. Field emission from individual WO_{3-x} nanowires was also studied in order to understand the high current emission mechanism. Based on the experimental results on field emission behavior of individual WO_{3-x} nanowires with different defect concentrations, it is proposed that the high current relates to the defect-induced transportation in the nanowire.

The results were supported by theoretical calculation using a model considering the defect-related electric transport and Joule heating in the field emission process. Our results are important for exploring a large area high brightness X-ray flat panel source.

P1-5.16 / Hydrothermally prepared reduced graphene oxide free standing film as high current field emitter

Dongpyo Hong (Seoul National University, Korea), Muhammad Mohsin Hossain (Seoul National University, Korea), Matlabjon Sattorov (Seoul-Teracom, Inc / Seoul National University, Korea), Seontae Kim (Seoul National University, Korea), Sun-Hong Min (Korea Institute of Radiological and Medical Sciences, Korea), Gun-Sik Park (Seoul National University, Korea)

Uniform, highly conductive, thin film field emitters are in immense need for future development of high power compact terahertz(THz) vacuum electronic devices(VED). Reduced graphene oxide(rGO) based free standing film as high current sheet beam cathode is fabricated by hydrothermal method. This hydrothermal method facilitates highly conductive, thin, compact film. We achieved to get few micrometers to sub-micrometer thick film which is much thinner than conventional vacuum filtered film resulting in higher field enhancement factor, current density, and current. This approach can successfully establish a fabrication method for uniform, thin high current field emitter for high power THz VEDs.

P1-5.17 / Planar Graphene Edge Field Emitter Design with Improved Emission Current

Jonathan L Shaw (U.S. Naval Research Laboratory, USA), John B Boos (KeyW Corporation, USA), Byoung Don Kong (POSTECH, Korea), J. Mittereder (U.S. Naval Research Lab, USA)

We demonstrate field emission from planar graphene edges fabricated using a new method. The device uses narrow cantilevered metal beams to support the graphene. To date we have measured emission currents over 10μA from edges less than 50μm long, three orders of magnitude improvement over previous results. Millikan-Lauritsen plots result in straight lines. The electron energy spectra demonstrate field emission but are sometimes broadened on the low energy side relative to standard field emission theory, suggesting the Fermi energy was shifted by up to several eV along the edge. The cause of the shift may be adsorbed fluorine atoms which reduce the electron density in graphene.

P1-5.18 / Field emission properties of polyacrylonitrile(PAN) carbon fibers of various processing temperatures

Htet Win Aung (Moscow Institute of Physics and Technology, Russia), E. P. Sheshin (Moscow Institute of Physics and Technology, Russia), Wai Zin Hlaing (Moscow Institute of Physics and Technology, Russia), Nyein Chan Kyaw (Moscow Institute of Physics and Technology, Russia)

All carbon materials used as auto electronic cathodes are nanostructured materials. Field emission of such materials occurs from micro beams having characteristic sizes from 0.1 to 100 nm. Polyacrylonitrile (PAN) carbon fiber consists of closely intertwined filamentous fibrils, the

length of which can reach 1 μm, diameter 1-5 nm.

P1-5.19 / Field emission properties thin foils based on carbon materials

Wai Zin Hlaing (Moscow Institute of Physics and Technology, Russia), Evgeny P. Sheshin (Moscow Institute of Physics and Technology, Russia), Htet Win Aung (Moscow Institute of Physics and Technology, Russia), Nyein Chan Kyaw (Moscow Institute of Physics and Technology, Russia)

All Carbon materials used as field cathodes belong to nanostructured materials. Field electron emission of such materials occurs from micro-protrusions having characteristic dimensions of 0.1-100 nm. Since carbon has a finite amount of compound (and all life on the planet Earth is based on this), all properties of carbon materials, including field emission materials, should be sought in their structure.

Poster 1

April 29 (Monday) / 15:10 ~ 16:30 / Capri room

Fabrication techniques / Materials

P1-6.1 / Influence of Diamond on Heat Dissipation Capability of The Helix Slow-Wave Structures

Yanwen Liu (Chinese Academy of Sciences, China), Hong Tian (Chinese Academy of Sciences, China), Yu-Xin Lu (Chinese Academy of Sciences, China), Wenqi Shi (Chinese Academy of Sciences, China)

Heat dissipation capability of helical slow-wave structure is an important factor that affects output power, operating stability and reliability of travelling-wave tube (TWT). As diamond material has superbly high thermal conductivity, use of it in fabricating helical slow-wave structure is able to improve heat dissipation capability of the component to some extent. By means of theoretical calculation, simulation & emulation and laboratory test, this paper studies influences of diamond-film- deposited support rod, diamond-film-deposited helix and diamond support rod on heat dissipation capability of slow-wave structure. With a contrast study of experiment and simulation data, the computer simulation is closely correlated to experimental test, which improves the accuracy of computer simulation research and offers important references for application of diamond material in slow-wave structure.

P1-6.2 / Study of A Nanocrystalline Diamond for Composite Diamond Windows in THz TWTs

Ming Q. Ding (Beijing Vacuum Electronics Research Institute, China), Lili Li (Beijing Vacuum Electronics Research Institute, China), Chengyi Hua (Beijing Vacuum Electronics Research Institute, China), Jun Cai (Beijing Vacuum Electronics Research Institute, China), Jinjun Feng (Beijing Vacuum Electronics Research Institute, China)

Previously we have developed an extremely thin composite diamond film for THz TWT windows by incorporating ultrananocrystalline diamonds (UNCDs) into microcrystalline diamonds (MCDs). Given that the processing conditions for UNCD differ from those of MCD, we investigated a process of nanocrystalline diamond (NCD) as an alternative to UNCD. This type of NCD is grown at relatively high substrate temperature (~870^{0}C) under the same gas mixture (CH4/H2) as MCD that the fabrication processing can be facilitated. Testing results show that the fabricated NCD films have an average mechanical strength of 1565±88 MPa, no less than UNCD.

P1-6.3 / Low Secondary Electron Yield Materials For Space Applications Based on Ab Initio Computation

Min Peng (Xi'an Jiaotong University, China), Yongdong Li (Xi'an Jiaotong University, China), Chunliang Liu (Xi'an Jiaotong University, China), Dawei Wang (Xi'an Jiaotong University, China)

Anti-multipactor in space microwave devices is of great significance in a vacuum environment. It contributes to overcome one important limiting factor, i.e, the high secondary electron emission (SEE), which threatens the safety of various microwave devices in spacecrafts. In this paper, based on existing models of SEE, the relationship between the secondary electron yield (SEY) and work function is discussed for metallic materials with different crystal planes. Furthermore, we have computed the work function for solid material surfaces and electron affinity for dielectrics using simulations, trying to establish a correlation between chemical constituents, atomic geometry and surface potential barrier of materials and to understand the influence of lattice structure and atomic arrangement on SEY. We have accurately computed the work functions of a few materials, including: (1) Work functions of metals and their oxides (with oxides showing higher maximum SEY); (2) Work functions for MgO and NiO single crystals, as well as superlattices made from them; (3) Work functions for metals (Cu, Ni) and graphene covered metals (Cu, Ni). Moreover, a method to avoid the sensitive area and reducing the SEY is proposed in the structure design, which is expected to come into experimental verification. At last, we focus on the scattering cross section underpinning most essential physical process of the secondary electron emission problem, and try to get a response from Monte Carlo simulation using the factors calculated above and the multi-generation model on rough surfaces.

P1-6.4 / W-band TWT Component Fabrication and Testing

Alan M. Cook (U.S. Naval Research Laboratory, U.S.A), Edward L. Wright (Beam Wave Research, Inc., U.S.A), Khanh T. Nguyen (Beam Wave Research, Inc., U.S.A), Colin D. Joye (U.S. Naval Research Laboratory, U.S.A), Frank. N. Wood (U.S. Naval Research Laboratory, U.S.A), B. Spence Albright, Jr. (U.S. Naval Research Laboratory, U.S.A), John R. Lowe (U.S. Naval Research Laboratory, U.S.A), Reginald L. Jaynes (U.S. Naval Research Laboratory, U.S.A), Jeffrey P. Calame (U.S. Naval Research Laboratory, U.S.A), David K. Abe (U.S. Naval Research Laboratory, U.S.A), Takuji Kimura (CPI, U.S.A), Galen Aymar (CPI, U.S.A)

We present fabrication and testing of RF components for a W-band serpentine waveguide TWT. Broadband ceramic RF windows and loads exhibit reflection lower than -20 dB across the TWT operating band, nominally 87-100 GHz. End-to-end cold test of the entire tube assembly, including interaction circuit, shows a clean passband better than -15 dB, in agreement with simulation. We discuss details of the fabricated components and electromagnetic cold test results.

P1-6.5 / 3D Printing of Microwave Attenuating of FeSiAl Materials

Yingqin Liu (Chinese Academy of Sciences / University of Chinese Academy of Sciences, China), Yongqing Zhang (Chinese Academy of Sciences, China), Guanghua Li (Chinese Academy of Sciences, China), Xiangjun Wang (Chinese Academy of Sciences, China), He Jin (Chinese Academy of Sciences, China), Xiangyang Gao (Chinese Academy of Sciences, China), Bofeng Wang (Chinese Academy of Sciences, China)

In this paper, we propose a novel method to prepare FeSiAl coatings. This method is laser 3D

printing technology of FeSiAl powder. Research shows that the FeSiAl coatings prepared by laser 3D printing still have good microwave attenuation performance.

P1-6.6 / Dielectric Material for the Electron Accelerator Vacuum Chamber

Tae-Yeon Lee (Pohang Accelerator Laboratory, Korea), Taekyun Ha (Pohang Accelerator Laboratory, Korea)

Ever since the first particle accelerator appeared in the early twentieth century, the vacuum chamber of any accelerator has been made of metals such as stainless steel or aluminum. These metals have not only an advantage of maintaining ultra-high vacuum but other advantages such as strength and durability. However, the image current induced on the metal chamber surface by charged particles moving inside the chamber is a main cause for instabilities occurring inside the charged particle beam. This paper shows that dielectric vacuum chamber made of such materials as ceramic or glass can be used for electron accelerators without generating image current and instabilities. This paper also shows how to resolve problems coming from dielectric vacuum chamber including charging effect and static charges.

P1-6.7 / Work Function and Electronic Structure Measurements on Nitrogen-Doped LaB_6 Thin Film by Scanning Tunneling Microscope

Katsumi Nagaoka (National Institute for Materials Science, Japan), Shun-ichiro Ohmi (Tokyo Institute of Technology, Japan)

Lanthanum hexaboride (LaB_6) is one of the most widely used low work function materials. However, for realizing the lowest work function of 2.3 eV, the single crystalline bulk material had been persuaded to be absolutely necessary for preventing surface degradation by oxidation. But, recently, a LaB_6 thin film exhibiting the low work function has been developed with radio frequency (RF) sputtering deposition using a nitrogen-doped (N-doped) LaB_6 target. Here we report an experimental study on the work function and electronic structure measurements on the 20 nm-thick N-doped LaB_6 thin film. We found, even after air exposure, annealing at 500 ℃ revived the work function of 2.35 eV and the local electronic structure consistent with the previous studies on the clean pristine single crystal. Our results demonstrate the N-dope LaB_6 thin film does not only maintain the fundamental properties of the pristine material but also greatly facilitate the handling. We anticipate that the N-doped LaB_6 thin film enables to extend the application scope of the LaB_6.

P1-6.8 / A microwave plasma jet chemical vapor depositionfor diamond film growth

Chun-Yu Lin (National Taipei University of Technology, Taiwan), Jing-Shyang Yen (National Taipei University of Technology, Taiwan), Hua-Yi Hsu (National Taipei University of Technology, Taiwan), Ming-Chieh Lin (Hanyang University, Korea)

The research and development of a microwave plasma jet chemical vapor deposition for diamond film growth have been carried out in this study. This three-dimensional microwave

plasma model helps understanding the operating conditions for the growth of diamond film. This mathematical modeling uses an adaptive finite element numerical method based on different parameters. Plasma simulation has been considered as a numerically stiff problem because of the strong nonlinearity and multi scales crossing. The whole system has been modeled soundly. Also, the thin diamond film has been successfully fabricated according to the identical condition. The SEM image shows that the deposited diamond particles are uniformly distributed on the substrate with the size of 1 μm which might find application in surface hardening and field electron emission.

P1-6.9 / Local work functions of magnetite under electric fields based on first principle calculations

Liangliang Xu (Hanyang University, Korea), Nan Zhao (Hanyang University, Korea), Ming-Chieh Lin (Hanyang University, Korea), Tsan-Chuen Leung (National Chung Cheng University, China)

Magnetite is a mineral and one of the main iron ores. With the chemical formula Fe_3O_4, it is one of the oxides of iron. Magnetite is the earliest discovered magnet, around 1500 B.C. It crystallizes in the inverse cubic spinel structure (Fd3m) above the so-called Verwey transition temperature which is about 120 K. In this work, we study the electronic properties of magnetite (100), (110), and (111) surfaces under external electric fields using first principles or ab initio calculations based on density functional theory. With an electric field applied, the effective work function changes under different field strength. By calculating the local work function, we can know the distribution of work function on a certain surface. The effective work functions of magnetite Fe_3O_4 on different surfaces have been determined. The local work function has been found to have the correspondences with the atoms' positions and charge densities. In addition, the deviation in local work function ($\Delta\varphi$) increases proportionally to an increasing electric field up to 0.2 V/A. It is proposed that the magnetite as a half-metal can possibly be used as a spin-polarized electron source.

P1-6.10 / Local work functions of clean tungsten surfaces under electric fields based on ab initio calculations

Yue Wang (Hanyang University, Korea), Liangliang Xu (Hanyang University, Korea), Ming-Chieh Lin (Hanyang University, Korea), Tsan-Chuen Leung (National Chung Cheng University, China)

Tungsten, the common choice for vacuum tube filaments, can survive under high temperatures and provide thermionic emission of electrons. However, the emission is largely limited due to its relatively high work function (approximately 4.5 eV). First principles or ab initio calculations are used to study the local work functions of tungsten (W) clean (100), (110), and (111) surfaces under external electric fields. The authors have systematically tested the convergence of density-functional-theory (DFT) calculations in the local-density approximation (LDA) and generalized-gradient approximation (GGA) with a plane-wave basis set the projector-augmented wave method as implemented in the Vienna Ab-initio Simulation Package (VASP). Several pseudo-potentials have been tested for comparison. With the tungsten model under electric fields applied on both sides, we can investigate the dependence of the local work function and

effective work function on field strength. In addition to thermionic emission, tungsten has been considered for use as a field emission (FE) electron source.

P1-6.11 / Twin Growth in RF Window Ceramic as a Criterion for the Response Time of Protection System in High Power Vacuum Tubes

Shahriyar Kaboli (Sharif University of Technology, Iran)

The ceramic fracture in output RF window is one of the most important failure factors in high power microwave sources. Fast protection systems are used to protect the source. The methods for determining the required protection response time are conservative and rough. In this paper, an investigation is presented about the twin growth in the ceramic of RF window in faulty condition. It is shown that the twin growth in ceramic can be a reliable figure of merit for the response time calculation of the microwave source protection system.

Poster 1

April 29 (Monday) / 15:10 ~ 16:30 / Capri room

FELs / BWOs / Cherenkov devices

P1-7.1 / An S-Band Reversed Cherenkov Oscillator in a Novel All-Metal Metamaterial Miniaturized Slow-Wave Structure

Xiaoyi Li (University of Electronic Science and Technology of China, China), Xirui Zhan (University of Electronic Science and Technology of China, China), Zhaoyun Duan (University of Electronic Science and Technology of China), Xin Wang (University of Electronic Science and Technology of China), Daxi Ji (Nanjing Sanle Group Co., Ltd, China), Yubing Gong (University of Electronic Science and Technology of China, China), Baidyanath Basu (Supreme Knowledge Foundation Group of Institutions, India)

A novel metamaterial slow-wave structure was proposed for an S-band reversed Cherenkov oscillator based on CST simulation. In view of the sub-wavelength and strong resonance characteristics of metamaterial, the slow-wave structure enjoyed both miniaturization and high coupling impedance. Taking, typically, the beam radius, voltage and current as 4.2 mm, 25 kV and 3 A, respectively, and the longitudinal focusing field as 0.2 T, the output power of the reversed Cherenkov oscillator was predicted as 20 kW with 27% electronic efficiency at 2.2 GHz operating frequency in a miniaturized configuration with a typical structure radius of only 20 mm. The proposed device with low beam voltage, miniaturized configuration and high efficiency has wide application prospects in narrowband communication, radar and accelerator.

P1-7.2 / Demonstration on Ring FEL as EUV lithography tool

Jaeyu Lee (Pohang Accelerator Laboratory, Korea) G. Jang (POSTECH, Korea), J. Kim (POSTECH, Korea), J. Ko (Pohang Accelerator Laboratory / POSTECH, Korea), 2 B-H. Oh (Pohang Accelerator Laboratory, Korea), Y. Parc (Pohang Accelerator Laboratory, Korea) ,S-S. Lee (Pohang Accelerator Laboratory, Korea), S. Shin (Pohang Accelerator Laboratory, Korea)

Extreme ultraviolet radiation lithography (EUVL) is widely recognized as a strong candidate to succeed 193 nm immersion lithography for patterning the most critical layers in integrated circuit manufacturing. Therefore, the development of radiation sources for EUVL has lately received a considerable attention. One of the promising candidate sources for EUVL is a free-electron laser (FEL) as a high-power radiation source. By using extremely low emittance beam from the 4th generation storage ring (4GSR) by-pass beamline, which consists of the 1st undulator as energy modulator, chicane as dispersive section and the 2nd undulator as radiator, was designed as FEL source for EUVL. High-gain harmonic generation (HGHG) scheme with by-pass beamline in 4GSR allows average power at 13.5 nm wavelength to increase up to 500 W. In this paper, we describe stat-to-end simulation result for Ring FEL as EUV lithography tool.

P1-7.3 / Powerful W-band Surface-Wave Oscillator based on High-Current Relativistic Sheet Electron Beam: Design and Simulations

Nikolai Yu. Peskov (Russian Academy of Sciences, Russia), Andrey V. Arzhannikov (Russian Academy of Sciences, Russia), Naum S. Ginzburg (Institute of Applied Physics Russian Academy of Sciences), Petr V. Kalinin (Russian Academy of Sciences, Russia), Evgeny S. Sandalov (Russian Academy of Sciences, Russia), Alexander S. Sergeev (Russian Academy of Sciences, Russia), Stanislav L. Sinitsky (Russian Academy of Sciences, Russia), Vasily D. Stepanov (Russian Academy of Sciences, Russia), Vladislav Yu. Zaslavsky (Russian Academy of Sciences, Russia)

Project of powerful planar W-band surface-wave oscillator is under development in collaboration between IAP RAS (N.Novgorod) and BINP RAS (Novosibirsk) at the "ELMI" accelerator 1 MeV / 5 - 7 kA / 3 μs. Electrodynamic system of this oscillator is based on a two-dimensional doubly-periodical structure, which combines the properties of a slow-wave system that realizes conditions for an effective Cherenkov interaction with a high-current rectilinear sheet electron beam, and a high-Q resonator that implements the mechanism of two-dimensional distributed feedback and provides selective excitation of the operating mode in the strongly oversized interaction space. Design parameters of the project are discussed and results of the simulations are presented, which demonstrate the possibility to achieve in the considered scheme a stable narrow-band regime of oscillation with the output power of the gigawatt level.

P1-7.4 / Rigime of multi-stage trapping in a sectioned system of profiled rf undulators

Sergei Kuzikov (Russian Academy of Sciences, Russian), Andrei Savilov (Russian Academy of Sciences, Russian), Alexander Vikharev (Russian Academy of Sciences, Russian)

We propose a high-efficiency regime of a "multi-stage" trapping in FELs. This FEL scheme use strongly tapered flying RF undulator sections to be fed by short (nanosecond) high-power RF pulses produced by already existing BWOs. In this regime, phase locking of the RF sources is not necessary. Moreover, this regime provides an effective amplification of a multi-frequency wave signal in the SASE regime used in typical short-wavelength FELs. In this work, we describe the proposed multi-stage regime, as well as profiled microwave system designed for the realization of tapered rf undulators.

P1-7.5 / Compact free-electron lasers using laser driven cascaded dielectric nano-pillar arrays

Linbo Liang (University of Science and Technology of China, China), Weihao Liu (University of Science and Technology of China, China), Qika Jia (University of Science and Technology of China, China), Lin Wang (University of Science and Technology of China, China), Yalin Lu (University of Science and Technology of China, China)

We proposed a concept of very compact free-electron lasers (FELs) using infrared lasers to drive cascaded dielectric nano-pillar arrays (DNPAs). It employs a preset section of DNPA, driven by the longitudinal polarized laser, to prebunch the electron beam via the longitudinal

velocity bunching mechanism. After drifting a certain distance, these electron bunches then enter the downstream cascaded sections of DNPA, which are alternately driven by transverse polarized lasers with phase shift of π. The electron bunches will wiggle synchronously (due to the deflecting forces exerted by the transverse polarized electric fields) in these DNPAs, which act as effective undulator in conventional FELs. By changing the length of these sections, the undulator periodicity, together with the undulator strength K-value, can be adjusted effectively. It sets a prototype to develop the ultraviolet and soft X-ray FELs with tabletop sizes.

P1-7.6 / Design of a photocathode DC-gun for generating train of sheet-shaped electron bunches

Linbo Liang (University of Science and Technology of China, China), Weihao Liu (University of Science and Technology of China, China), Qika Jia (University of Science and Technology of China, China), Lin Wang (University of Science and Technology of China, China), Yalin Lu (University of Science and Technology of China, China), Yen-Chieh Huang (National Tsinghua University, Taiwan)

Using the superradiant Smith-Purcell radiation from a train of periodic electron-bunches interacting with a grating is an efficient way forgenerating terahertz radiation beyond the frequency region of traditional vacuum electron devices. The producing of a train of well-shaped electron bunches is essential for these radiation schemes. Here we design and simulate a photocathode DC-gun driven by train of laser pulses, aiming to generating train of sheet-shaped electron bunches for practices. The effects of main structural parameters and of laser properties on the performances of electron gun are investigated. It will set an important base for the development and improvement of practical electron guns in experiments.

P1-7.7 / Optimization of 0.1 THz Planar Interaction Structure for Higher Efficiency

Subhendu Chakraborty (The University of Burdwan, India), N. Purushothaman (CSIR-CEERI, India), Nikita Gurjar (CSIR-CEERI, India), Niraj Kumar (CSIR-CEERI, India), R. K Sharma (CSIR-CEERI, India)

In this paper, simulation studies on 0.1 THz planar slow wave interaction structure for Backward Wave Oscillators (BWOs) have been presented. The normalized phase velocity and dispersion variation profiles for different beam tunnel width to height ratios are analyzed using Eigen mode simulations in CST Microwave Studio. Axial electric field amplitude with interaction impedance profile for different aspect ratios, are also analyzed as a optimization study of effect of beam tunnel width to height ratio with the BWO operation and its frequency range.

P1-7.8 / 220GHz Sine Waveguide BWO with large Beam Tunnel

P. C. Yin (University of Electronic Science and Technology of China, China), H. R. Yin (University of Electronic Science and Technology of China, China), J. Xu (University of Electronic Science and Technology of China, China), S. Z. Fang (University of Electronic Science and Technology of China, China), X. Lei (University of Electronic Science and Technology of China,

China), G. X. Wu (University of Electronic Science and Technology of China, China), L. N. Yue (University of Electronic Science and Technology of China, China), G. Q. Zhao (University of Electronic Science and Technology of China, China), W. X. Wang (University of Electronic Science and Technology of China, China), Y. Y. Wei (University of Electronic Science and Technology of China, China), Luqi Zhang (Huawei Technology Co., Ltd. China), Dazhi Li (Institute for Laser Technology, Japan)

The development of 220GHz sine waveguide BWO with cylindrical beam tunnel is presented here. The particle-in-cell (PIC) simulation result predicts that this device can product the output power over 6.5W in frequency range of 214.07GHz to 224.99GHz. The radius of beam tunnel is 0.2 mm. The beam current is chosen as 70mA which has a current density of 99A/cm^2. The uniform magnetic is 0.25T.

P1-7.9 / O-Type Millimeter-Wave Band Devices on the Spiral Bent Rectangular Waveguide

Alexander Kurayev (Belarusian State University of Informatics and Radioelectronics, Belarus), Alexey Rak (Belarusian State University of Informatics and Radioelectronics, Belarus), Artem Badarin (Innopolis University, Russia), Semen Kurkin (Innopolis University, Russia), Alexey Koronovskii (Saratov State University, Russia)

The designs of O-type millimeter-wave band devices with two wide tape electron beams are proposed and investigated. It is proposed to use a spirally bent rectangular waveguide on fundamental H10 mode as an electrodynamic structure of the tubes. Analytical estimates have shown the possibility of effective interaction of the electron beam with both direct and backward electromagnetic waves for the certain values of control parameters of the systems.

P1-7.10 / Optimization of Volume Free-Electron Laser with Photonic Crystal Foil Grid Structure for Operation in Sub-Terahertz Range

Artem Badarin (Innopolis University, Russia), Nikita Frolov (Innopolis University, Russia), Semen Kurkin (Innopolis University, Russia), Alexey Rak (Belarusian State University of Informatics and Radioelectronics, Belarus)

In this work we present the results of numerical optimization of volume free-electron laser based on the interaction between electron beam and periodic structure of microwave photonic crystal. The optimization aims at advancement of such device to sub-terahertz frequency range. We show that reduction of characteristic geometric dimensions allows to increase the oscillation frequency of photonic crystal fundamental mode f_0 up to 12.5 GHz. Moreover, we observe the possibility to generatemicrowaves at higher harmonics of fundamental frequency, namely at $f_5 = 5 \times f_0 = 62.5$ GHz, and obtain output power level of about 3.6 kW.

P1-7.11 / Hybrid Microwave Device Based on the Vircator with Additional Electrodynamic Section

Andrey Starodubov (Saratov State University, Russia), Nikolay Kuznetzov (Saratov State

University, Russia), Alexey Koronovskii (Saratov State University, Russia), Yurii Kalinin (Saratov State University, Russia)

The results of the study of a microwave generator based on a nonrelativistic low-voltage vircator with a non-laminar electron beam and with an additional extended electrodynamics section are presented. An additional extended electrodynamics section based on the slow wave structure of helix type. It is shown that the proposed device has the efficiency of 20% with a frequency band of 1-3 GHz.

P1-7.12 / Low Starting Current Oscillator Based on the Degenerate Band Edge in a Double Helix Slow Wave Structure

Ahmed F. Abdelshafy (University of California Irvine, USA), Tarek Mealy (University of California Irvine, USA), Alexander Figotin (University of California Irvine, USA), Filippo Capolino (University of California Irvine, USA)

We present a new slow wave structure (SWS) for high-power electron-beam-driven oscillators based on the degenerate band edge (DBE). The proposed DBE operational regime is based on four degenerate eigenmodes all synchronized with the electron beam, and leads to an effective energy transfer from the electron beam to the four degenerate eigenmodes. This paves the way for a new class of high-power oscillators, which we have called degenerate band edge oscillators (DBEOs) that show an unconventional trend of the starting current and feature single frequency of oscillation with high spectral purity.