# 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**

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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**

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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**

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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**

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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**

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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**

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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**

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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**

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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**

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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**

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(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.