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.