

Operation of a free-electron maser based on two-dimensional distributed feedback

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First measurements of microwave radiation from a co-axial Free-Electron Maser (FEM) based on two-dimensional (2D) distributed feedback are presented. To drive the FEM a high current accelerator (HCA) based on a magnetically-insulated explosive emission carbon cathode was used. An accelerating voltage 450 kV and pulse duration of ~ 200 ns was applied to the cathode which produced a thin (0.2cm) annular electron beam of current 500A and mean diameter of 7.0 cm. The electron beam was guided through a co-axial transmission line of length ~ 2 m with the diameters of inner and outer conductors of 6 and 8 cm respectively. An azimuthally symmetric undulator of period 4 cm was located inside the uniform magnetic guide field. The undulator field was slowly up-tapered over the initial 6 periods. A solenoid of length 2.55m and diameter 0.3m surrounding the co-axial electron gun, undulator and co-axial transmission line interaction region was used to guide the electron beam. The amplitude of the undulator magnetic field could be varied up to 0.06 T while the amplitude of the guide magnetic field could be increased up to 1T. A two-mirror cavity of length 81 cm (input 2D Bragg mirror 10.4 cm, output 2D Bragg mirror 5.6 cm) was located inside the transmission line along the uniform part of the undulator. To measure the output radiation from the FEM two Ka-band (26.5 to 40GHz) receiving horns with 55dB of attenuation with HP8474E (0.01-50GHz) detectors were located at a distance of 1.5m from the output window. The position of the second horn was free to move and was used to study the output radiation mode pattern. A TEM wave radiation pattern launched from the FEM conical co-axial horn of inner and outer diameter 6cm and 19cm respectively was measured. The output power of the FEM was measured by integrating the power densities over space. The total power was calculated to be 14 (± 0.15) MW. Additional evidence of the high peak power was obtained from the observation of the illumination of a neon bulb panel when the microwave signal irradiated the panel at a distance of 20cm from the output window. A heterodyne frequency diagnostic was used to measure the frequency of oscillation. Microwave radiation from the FEM was mixed in a non-linear Farran Technology waveguide balanced mixer BMC-28B. At a local oscillator (LO) frequency of 38GHz the resultant intermediate freq (IF) was recorded on a deep memory digitising oscilloscope with a single shot bandwidth of 1.5GHz. The spectrum of the mixed signal was plotted by taking the Fourier transform of the IF signal. Knowing the LO frequency, the spectra of the output radiation was measured to be 37.3GHz.

With a beam energy of 450keV and current of 500A, the oversized FEM oscillator achieved a maximum output power of 14MW, at an oscillating frequency of 37.3GHz, and an efficiency of 6%. Using a novel 2D Bragg cavity the measured parameters of the FEM were in good agreement with theory. Future work will involve optimising the cavity configuration to achieve higher efficiency and higher power operation.