High Power Masers based on 2D periodic structures: from the GHz to THz frequency range

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***Abstract*—High power millimeter and sub-millimeter wave sources operating in the high GHz – THz (35GHz-1THz) frequency range are important for a number of applications. This work will focus on the overview of recent theoretical and experimental research conducted at the University of Strathclyde to design, build and study masers operating at 37.3GHz, 91.2GHz and 0.74THz. The results obtained will be presented and discussed.**

I. Introduction

The demand for high power devices operating in the millimeter and sub-millimeter wave regions is steadily increasing. Such sources are important for a number of applications; including remote sensing, spectroscopy, medical diagnostics, material sciences and security. In order to achieve the desired high power radiation at such frequency ranges the use of large diameter high current but low current density beam is suggested [1]. This has two distinct advantages; firstly the low space charge density avoids the formation of beam instabilities and secondly the electromagnetic power density inside the cavity can be maintained at a level which circumvents electromagnetic field breakdown inside the interaction space. In order to synchronize the radiation from different parts of the large diameter beam, the application of a 2D periodic structure to realize the distributed feedback has been used [2-4]. The periodic perturbations which define the structure are in the form of a two dimensional square wave lattice. In recent years the studies involving the use of this type of lattice have been successfully performed [4,5] and excellent potential for application of the high power masers has been demonstrated.

II. Results

A two-mirror Free Electron Maser operating at 37.3GHz, based on two dimensional distributed feedback and driven by a 1.5 kA, 8 cm diameter annular electron beam has been recently built and studied at Strathclyde. An output power of 65MW was measured. The comparison of the voltage and microwave pulse is shown in fig.1a. The spectrum of output signal, which was observed using a heterodyne technique, is shown in fig.2. Further optimization of the electron beam will result in an increase in the electron current up to 3kA and hence power in the beam of up to 1.5GW.

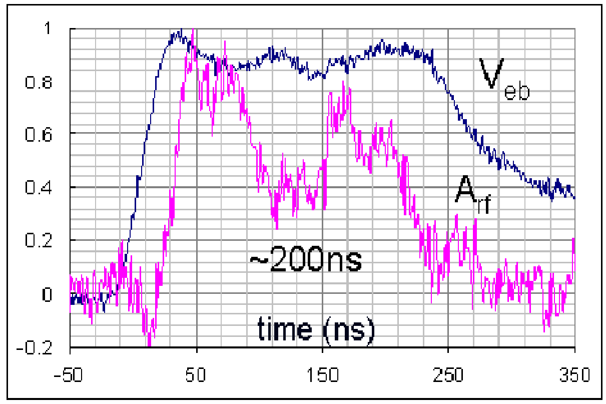

Fig.1. Comparison of the voltage and RF signal pulses

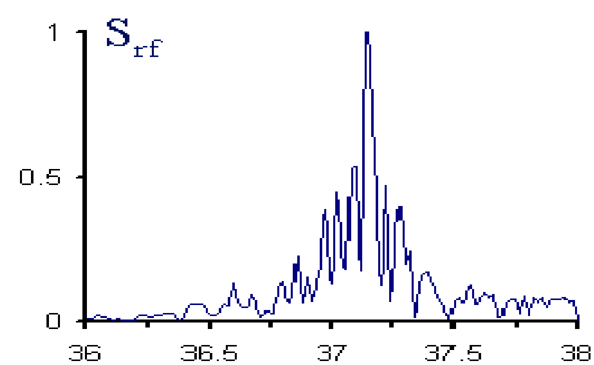

Fig.2. The spectrum of the output signal

Theoretical studies of a Cherenkov maser based on 2D periodic lattice have been carried out using the 3D Particle in Cell code MAGIC and preliminary design completed. The maser design was based on a 2cm diameter cylindrical waveguide with a doubly periodic corrugation on the inner surface, having 16 azimuthal variations and a 3.2mm corrugation period. The maser was driven by a 1.6kA annular electron beam having a 0.86cm radius and single particle energy of 300keV. Results demonstrate the maser was capable of generating a maximum power of ~22MW, fig. 3a, at the single frequency of 91.4GHz, fig. 3b, when the optimum guide field was 6 Tesla, shown in fig. 3c. The interaction region is 4.48cm in length and has a corrugation amplitude equal to 1mm.

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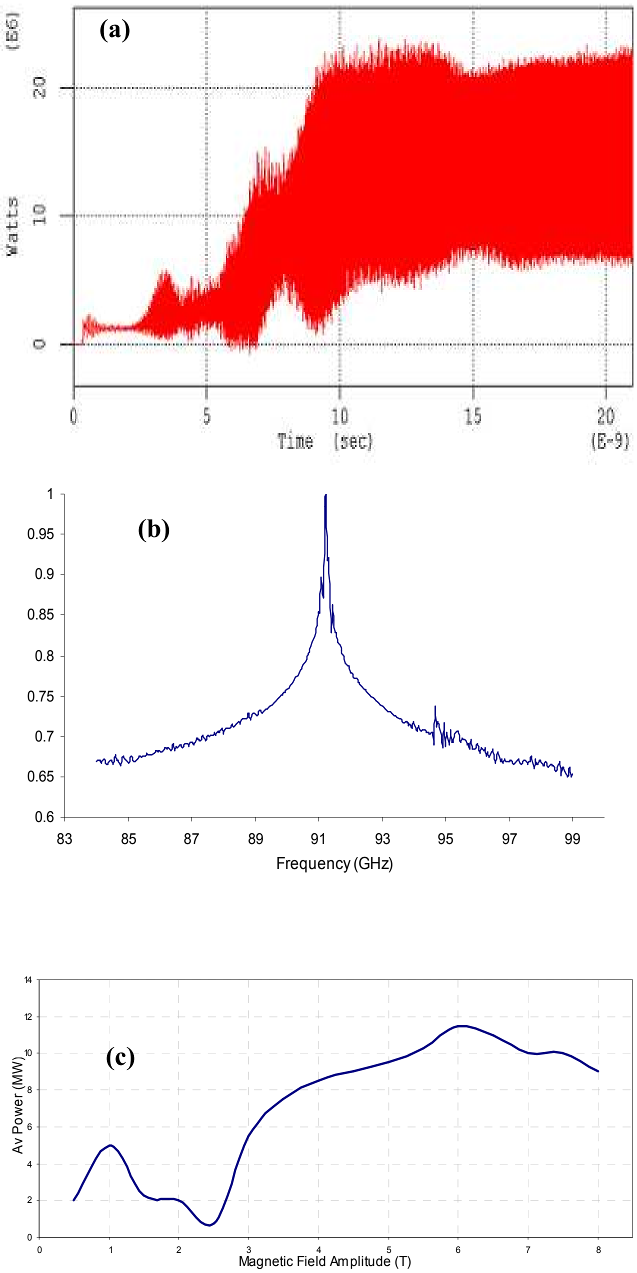

Fig.3 **(a)** The spectrum of output radiation, **(b)** the time evolution of the output power and **(c)** the average power variation with magnetic field amplitude

Future work will involve further study of masers based on a 2D periodic lattice. Preliminary simulations indicate that THz frequencies can be generated using masers based on 2D distributed feedback and driven by an oversized electron beam. In fig.4 the results of simulation of Smith-Purcell (SP) masers are shown and single mode operation demonstrated.

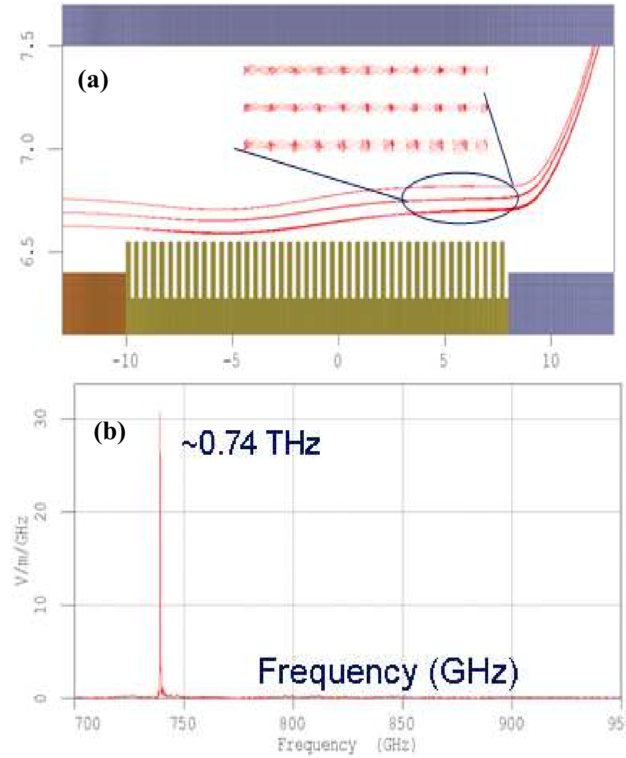

Fig.4 **(a)** Electron beam propagation through the interaction space of SP maser **(b)** the spectrum of output radiation.

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