THE SUB-MILLIMETER FEL FACILITY AT THE ENEA FRASCATI RESEARCH CENTER

F.Ciocci, G.Dattoli, A.De Angelis, A.Dipace, A.Doria, G.P.Gallerano, M.F.Kimmitt*, G.Messina, A. Renieri, E.Sabia, A.Torre, J.E.Walsh**

ENEA, Dip. Sviluppo Tecnologie di Punta, CRE Frascati, P.O.Box 65, 00044 Frascati (Rome) Italy

Abstract

A compact FEL facility designed to operate in the far-infrared and sub-millimeter regions of the spectrum has been realized at the ENEA research center of Frascati.

Results obtained with a dielectric loaded waveguide (Čerenkov-FEL) will be presented.

Introduction

A sub-millimeter FEL facility which utilizes a 5 MeV microtron as electron beam source (see Tab. I) has been developed in our research center within the framework of the Project for Optical and Electrooptical Technologies.

Table I - Electron beam parameters

e-beam energy	5 MeV
e-bunch duration	20 ps
macropulse duration	5 μm
average current	200 mA
peak current	4 A
vertical emittance	6 π mm mrad
horizontal emittance	18 π mm mrad
energy spread	0.5 %

Low energy, r.f. electron beam sources have indeed a potential application as driver for FEL operating in the far-infrared, since they can provide short pulses of coherent radiation in a spectral region not covered by conventional lasers.

The lay-out of the facility is sketched in Fig. 1. A resonator chamber, which allows a "straight-line" electron beam propagation, has been designed and realized in order to be used as a test-bed for different short-length guiding structures (up to 40 cm length) as:

- dielectric loaded waveguides (Čerenkov-FEL) [1]
- metal gratings (Orotron) [2]
- short period undulators.

Beam position monitors are included in the resonator chamber, together with an insertable 45° copper mesh reflector, which is used to extract the radiation coming out of the resonator.

The first application of this facility has been the test of a Čerenkov-FEL device.

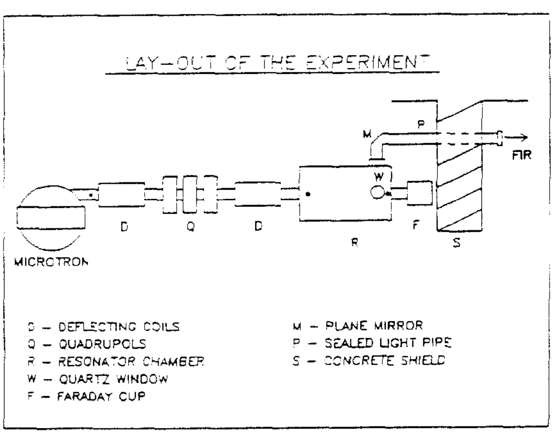

Fig.1 - Lay-out of the facility

Čerenkov-FEL Experiment

This type of FEL source is based on the interaction between a beam of relativistic electrons and the evanescent field of a surface wave produced in a dielectric loaded waveguide (see Fig. 2) [3,4].

The wavelength of the emitted radiation is in a first approximation proportional to the thickness of the dielectric film and to the electron energy, according to the relationship:

$$\lambda = 2\pi d\gamma \frac{\varepsilon - 1}{\varepsilon} \tag{1}$$

which is valid for $\gamma \gg 1$ and $\lambda \gg d$, where γ is the relativistic factor and ε the dielectric constant of the film.

A quasi optical resonator with a novel electron beam injection scheme and an "electron transparent" output coupler has been utilized for the experiment.

The resonator is composed of a diamond machined flat copper plate 310 mm long and 25 mm wide, coated with a polyethylene film (see Fig. 3).

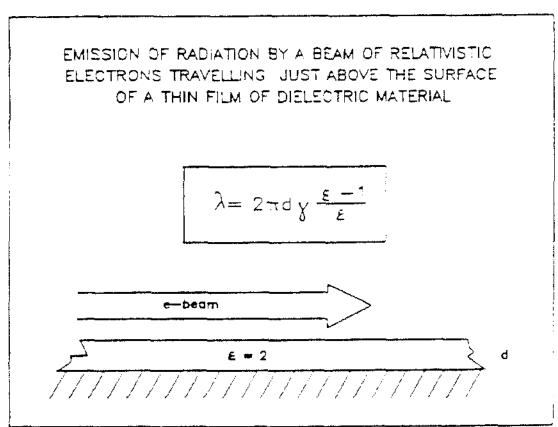

Fig.2 - Scheme of the interaction process

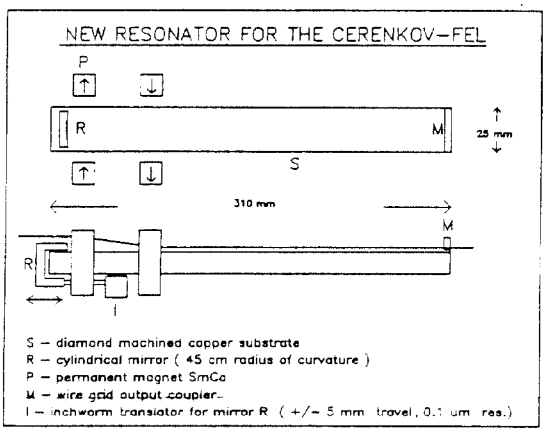

Fig.3 - The quasi optical resonator

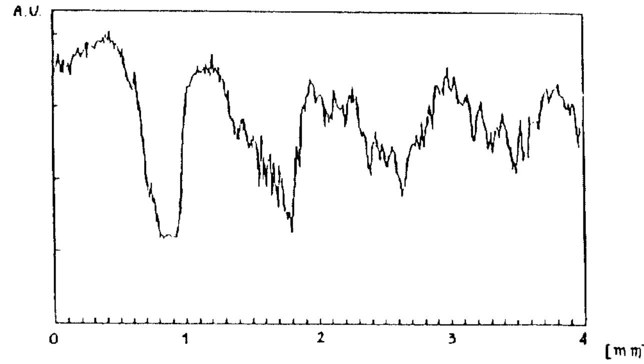

Fig.4 - Fabry-Perot interferogram for the 50 μm dielectric film

A 3 mm high cylindrical copper mirror, 450 mm radius of curvature is used at one end of the resonator for confining the optical mode in the horizontal plane. The mirror can be moved along the optical axis, to tune the resonator length, by means of a piezoelectric inchworm translator.

A wire grid reflector in contact with the copper plate is used as output coupler. Two couples of small permanent magnets, placed simmetrically sideways at the entrance of the resonator, allow the electron beam to enter the resonator above the input mirror and be then parallel displaced close to the surface of the dielectric film. the gap between the magnets can be remotely adjusted in order to optimize the coupling of the electrons to the dielectric film.

Experimental mesurements have confirmed the excellent injection properties of this structure.

Experimental Results

The Čerenkov-FEL device has been successfully operated at wavelengths of 900 μm and 1.6 mm employing polyethylene films of 25 μm and 50 μm respectively and no resonator.

The produced output power ranges between 20-100 W over a macropulse duration of 4 μs.

An analysis of the spectral properties of the emitted radiation (see Fig.4) performed with a wire grid Fabry-Perot, has shown a linewidth of several percent in agreement with the theoretical predictions.

Footnotes and References

* ENEA Guest. Permanent address: University of Essex, Colchester, U.K.

** Dept. Phys. and Astronomy, Dartmouth College, Hanover, NH USA

[1] F.Ciocci et al., "Status of the ENEA-Dartmouth FIR Cerenkov laser experiment", Nucl. Instr. Meth., A259,pp. 128-132, 1987

[2] J.E.Walsh, "A proposed FIR-IR Metal-Grating FEL experiment", Proceeding of 9th Int. FEL Conf., August 1989, Naples (USA), to be published in Nucl. Instr. Meth.

[3] F.Ciocci et al., "Spontaneous emission in Čerenkov-FEL devices: a preliminary theoretical analysis", Il Nuovo Cimento, Vol.10D(1), pp. 1-20, 1988

[4] G.Dattoli et al., "A single-particle calculation of the Čerenkov-FEL gain", Il Nuovo Cimento, Vol.101B(1), pp. 79-84, 1988