SPONTANEOUS EMISSION AS A TEST FOR THE PERMANENT MAGNET ENEA UNDULATOR

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Introduction

The radiation emitted by relativistic electrons moving in magnetic undulators is exploited in a variety of ways, ranging from pure to applied science [1]. Furthermore, Free Electron Laser (FEL) facilities are now being added to the conventional synchrotron light facilities [2].

The spectral characteristics of the undulator radiation (UR) emitted in the visible, uv, vuv, X-ray regions of the spectrum by electrons moving in a Storage-Ring have been deeply analyzed from the experimental point of view and well understood theoretically [3]. More recently, mainly in connection with FEL operating with low energy accelerators [4], (Microtrons, Linac, etc.) a significant ammount of literature has been devoted to the UR in the infrared (IR) region of the spectrum.

UR has not yet been exploited for specific applications in this region, but its prospective importance as diagnostic tool has been stressed elsewhere [5,6].

The possibility of using UR for "diagnostic" purpuses follows from the naive consideration that its spectral characteristics are affected by the qualities of the e-beam and by the shape of the undulator itself [7,8]. Serious efforts have been therefore undertaken to develop computer codes which include the details of an actual experiment, namely the beam energy spread and emittances and the measured magnetic map of the undulator. The above effects have no separated functions, for istance the emittances or a non perfect beam injection may affect the spectral characteristics in the same way as to a "non perfect" undulator field.

The present note is an attempt of discussing the UR radiation in the IR as a diagnostic tool along the above lines, considering the experimental results recently obtained at the ENEA Frascati center within the framework of the FEL microtron experiment [9]. We will discuss both the experimental and simulation results with particular emphasis on the effects due to e-beam and undulator qualities.

Experimental Apparatus And Methods

The ENEA-Frascati FEL has been designed and realized in order to produce coherent radiation in the medium infrared region of the spectrum and is driven by a 20 MeV microtron.

The main parameters of this microtron are the 4 A current over 20 ps of micro-bunch duration, 4 μm to 12 μm macro-pulse duration and 0.12% of energy spread. The horizontal and vertical emittances were measured by mean of a video digitizing system and an interfaced computer with which we analyzed the images coming from a fluorescent target, calculating the e-beam transverse distributions as a function of a quadrupole current. The results of these measurements gave us: 1.9 πmm mrad for the vertical emittance and 4.4 πmm mrad for the horizontal one.

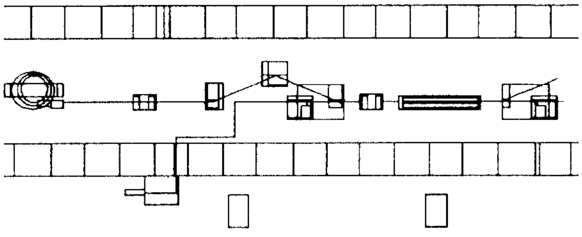

Fig.1 - Layout of the experiment.

The experiment utilizes a variable gap (from 0.9 to 7 cm) permanent magnet (SmCo) undulator with 5 cm period length and 45 periods [10]. A schematic layout of our FEL is given in Fig.1.

The optical diagnostic system is a complex one because we had to collect the infrared spontaneous emission 8 m downstream the entrance of the undulator, by mean a ZnSe lens with f=150 mm focal length. The radiation is also leaded out of the bunker to avoid X-ray and radiofrequency pick-ups on the optical detectors and amplifiers.

The radiation is analized on the focal plane by a 0.25 m spectrometer with several gratings.

Different detectors are utilized in the experiment like helium cooled Ge:Zn photoconductive detector (2x2 mm active area) or helium cooled Ge:Cu photoconductive detector (1x1 mm active area).

All the optical diagnostic system, like the electron beam one, is remote controlled by a computer via a fiber optic interface extender; a pre-analysis of the data is done by the same computer.

Spectra of radiation emitted in a cone $\Delta\theta = 5$ mrad were measured for different values of the undulator gap; different harmonics were selected using band-pass or cut-on filters.

Experimental results will be discussed together with the simulations in the next section.

Comparison between Experimental Results and Simulations

The simulation has been performed using the "S-Luce" code discussed in ref. [7]. In Fig. 2 we show the comparison between themeasured spectrum and the results from the simulation.

The measured spectrum is, in this case, significantly larger than the predicted one, since in the latter case the e-beam has been assumed matched in the undulator (i.e.in the calculation the beam section which minimizes the effect of the inhomogeneous broadening due to the emittance, is used). The theoretical results relevant to Fig. 2 have been obtained using the real trajectory of the electrons moving in the undulator, since at K=0.6 (undulator gap

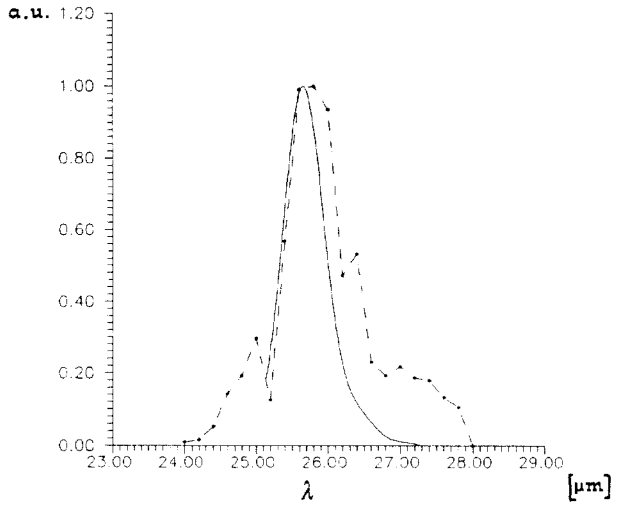

Fig.2 - Comparison between the experimental (dotted line) and theoretical one (solid line) 1st. harmonic spectra at K=0.6 (matched e-beam).

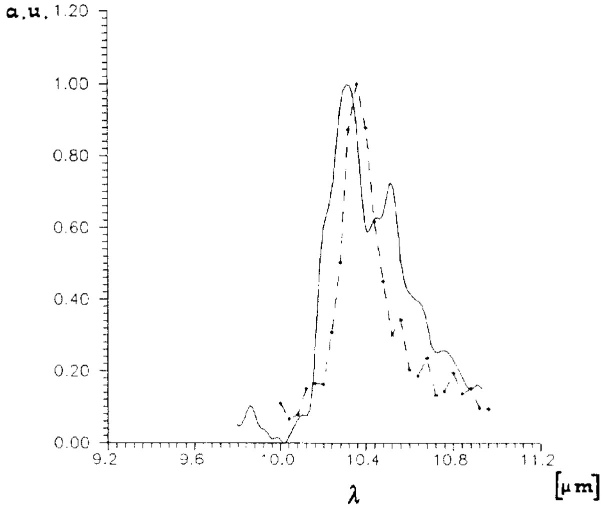

Fig.4 - Comparison between experimental (dotted line) and theoretical (solid line) 3rd. harmonic spectrum, K=0.8 (ideal and non matched e-beam)

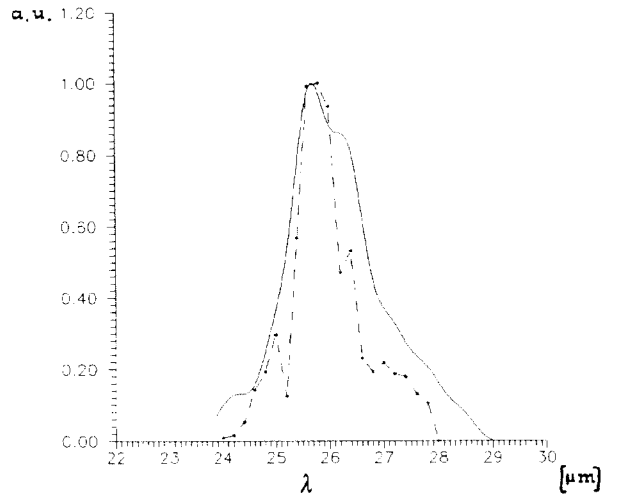

Fig.3 - Same as in fig.2 (non matched beam)

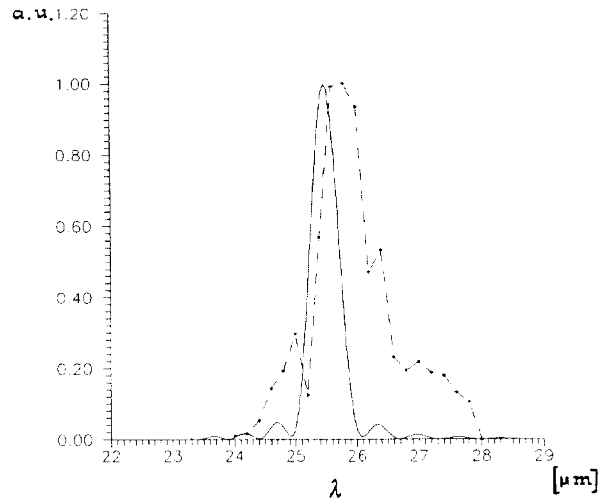

Fig.5 - Same as fig.2. The theoretical spectrum refers to an ideal beam (no energy and no emittances) and to the real undulator structure

of approximately 31 mm) the field map was accurately measured.

In Fig. 3 we have relaxed the assumption of matched beam, using the real Twiss coefficients in the undulator, and the significant effect is a broadening of the theoretical curve and a better agreement with the experimental results. It is worth stressing that the position of the peak can be used as a check for the correctness of the energy value.

In Fig. 4 the comparison is reported for the third harmonic spectrum. The agreement is particularly good, but we must underline that in the simulation the ideal e-beam trajectory has been used, since at K=0.8 (corresponding to an undulator gap of 25.6 mm) the field map was not avaible. The conclusion which can be drawn from this last result is that the possible undulator imperfections play a minor role and that the spectrum broadening is essentially due to the beam qualities.

To give a feeling of the importance of the inhomogeneous broadening contributions induced by the U.M. structure, in Fig.5 we show the comparison between the 1st. harmonic experimental spectrum and that calculated using an ideal e-beam (no energy and no emittances) and the measured undulator field. The theoretical spectrum shape is indeed very close to the ideal one, thus confirming the hypothesis put forward before.

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