ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-86/69

M. Ambrosio, G.C. Barbarino, M. Castellano, N. Cavallo, F. Cevenni,
M.R. Masullo, P. Patteri and M. Preger:
OPTICAL CAVITY OF THE ADONE FEL EXPERIMENT

Estratto da:
Nucl. Instr. & Meth. in Phys. Res. A246, 63 (1986)

Servizio Documentazione
dei Laboratori Nazionali di Frascati
Cas. Postale 13 - Frascati (Roma)

Nuclear Instruments and Methods in Physics Research A246 (1986) 63–66
North-Holland, Amsterdam

OPTICAL CAVITY OF THE ADONE FEL EXPERIMENT

M. AMBROSIO, G.C. BARBARINO, M. CASTELLANO, N. CAVALLO, F. CEVENNI and M.R. MASULLO

Instituto Nazionale di Fisica Nucleare, Sezione di Napoli, Napoli, Italy

P. PATTERI and M. PREGER

Instituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, Frascati (Roma), Italy

A detailed description of the parameter choice for the LELA optical cavity is presented. Particular attention has been devoted to the alignement problems solved by means of a remote control system. First results on mirror damage due to UV radiation will be also reported.

1. Introduction

The LELA (Laser ad Elettroni Liberi in Adone) is a feasibility experiment designed in order to study problems involving the interaction between radiation and the recirculating electron beam of a storage ring (Adone of LNF) [1] using a transverse electromagnetic undulator of 20 periods. The main characteristic of the experiment are summarized in table 1.

After the installation of the undulator, accurate spontaneous radiation [1] and optical gain [2–4] measurements have been worked out. Now an optical cavity of about 17.5 m has been built by prolongating the vacuum vessel of the Adone storage ring. Due to the very small peak gain (3×10^{-4}) the cavity has been designed to operate in high vacuum condition avoiding the use of any intracavity window which could increase the losses.

Table 1
Main characteristic of the experiment

Machine	
Energy	$E = 550$–625 MeV
Circumference	$L_c = 104.96$ m
Bunch to bunch distance	$\Delta t = 117$ ns
Fractional energy spread	$\sigma_p = 2.3 \times 10^{-4}$
Bunch length	$\sigma_t = 350$–1000 ps
RF frequency	$f_z = 51$ MHz
Number of bunches	3
Undulator	
Undulator period	$\lambda_w = 11.6$ cm
Number of periods	$N = 20$
Length (with clamps)	$L_w = 2.412$ m
Maximum magnetic field on axis	$B_0 = 4.95$ kG
Field parameter	$K = 4.825$

In this paper a brief description of the problems encountered in this construction is presented. Sect. 2 deals with the undulator features while the mechanical design characteristics are summarized in sect. 3. The remote control using piezoelectric (PZT) pushers and the preliminary experimental tests performed in order to obtain a good alignment of the cavity are described in sect. 4. In the last section some preliminary results about the mirror damage caused by the UV components of the spontaneous radiation are reported.

2. Characteristics of the LELA undulator

The electromagnetic undulator installed in a straight section of the Adone storage ring has 20 periods. It has been designed to have the smallest period ($\lambda_w = 11.6$ cm) to reach short wavelengths and to give a maximum vertical magnetic field on axis $B_y = 4.95$ kG.

The corresponding field parameter K has, in such a way, a value large enough to provide the spontaneous radiation spectrum with an extremely rich presence of harmonics in the UV range.

This fact is one of the major problems involved in the radiation damage of the cavity mirrors as it can be seen in sect. 5.

Accurate measurements of the angular and spectral distribution of the spontaneous radiation from the undulator were performed in the first stage of the experiment [1]. The obtained results fit very well the calculated distribution showing no distortion due to a "not ideal" magnetic field. In fig. 1 one of the measured radiation spectra is shown.

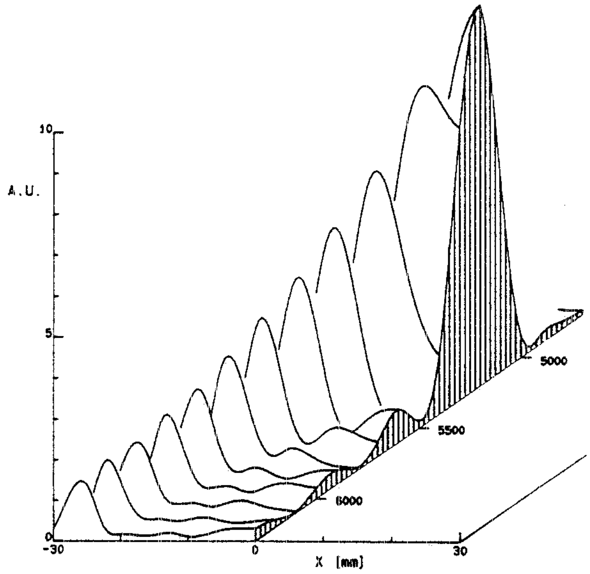

Fig. 1. Threedimensional distribution of the measured intensity vs the wavelength and off-axis angle (see ref. [1]).

3. Optical cavity parameters choice

The optical cavity has been dimensioned imposing the following restrictions:

(a) total losses per pass $\alpha \sim 10^{-4}$ due to the low gain ($\sim 10^{-3}$);

(b) cavity length equal to the half path covered by the electrons in the time lag between two successive bunches;

(c) Rayleigh length z_R of the cavity fundamental mode coinciding with a suitable fraction of the undulator length;

(d) low sensitivity of the cavity axis position, for the cavity fundamental mode, as a function of the mirror rotations;

(e) alignment of the optical axis on the electron trajectory within 15 μrad;

(f) cavity fundamental mode waist in the undulator center within ± 10 cm, keeping into account the tolerances for curvature radii of the mirrors;

(g) small mirror sizes to reduce costs;

(h) asymmetry with respect to the undulator center due to the presence of concrete radiation shielding.

To meet these requirements a cavity has been built in 1984 with the characteristics [5], listed in table 2.

Table 2
Cavity characteristics

No window between mirrors and accelerator pipe, the complete cavity under 10^{-9} Torr vacuum	
Cavity length	$L = 17.5$ m
Upstream mirror curvature radius	$R_1 = 7$ m
Downstream mirror curvature radius	$R_2 = 12$ m
Mirrors reflectivity at 6328 Å	$R = 99.97\%$
Fundamental cavity mode waist at 6328 Å	$w_0 = 0.68$ mm
Diffraction losses	$\alpha < 10^{-4}$
Rayleigh length	$z_R = 2.4$ m

Fig. 2. View of the gimbal mount mirror holder with PZT translator.

4. Remote controlling of the mirror movements

The mirrors are placed in a high risk radiation area. This fact forced us to implement a remote control for mirror movements. In order to obtain the necessary sensitivity the rotation of the gimbal ring is actuated by means of Burleigh's vacuum version PZT pushers (fig. 2). These devices, guaranteed for operating up to 10^{-6} Torr, have been successfully used at 10^{-9} Torr. A suitable coupling of two pushers with different excursions, head-to-head mounted in order to sum their effects, allows mirror tilting with a sensitivity of about 0.2 μrad/V and a total excursion of 1.5 mrad.

PZT transducers exibit substantial nonlinearity and hysteresis. It is therefore necessary, in order to obtain accuracy in the angular setting of the mirrors, to eliminate the errors introduced by these causes. We decided to follow the hysteresis loop always in the decreasing direction. The pushers have been accurately characterized by means of interferometric measurements, recording the typical extention as a function of the applied voltage along the hysteresis loop.

Using an external Ar laser (the same by which the optical gain has been measured) it is possible to align the cavity between 200 and 300 μrad. These values are fully within the operating range of the piezoelectric pushers. The nonlinear characteristic and the hysteresis loop of these pushers have been verified under high vacuum conditions using an external laser beam reflection upon a 20 m lever arm. The obtained results are shown in fig. 3. In the figure two successive cycles are represented demonstrating the fully reproducibility of the obtainable positioning within 0.2 μm. The alignment stability of the optical cavity upon a long range was better than 9 μrad. Further tests, either with an external laser or using the spontaneous radiation, proved a very good reliability and sensitivity of the whole system [6].

It is worthwhile emphasizing that a 17.5 m cavity alignment within 10 μrad, using completely automatized PZT pushers and having as diagnostic means only the radiation coming out from the cavity itself, has never been realized up to now.

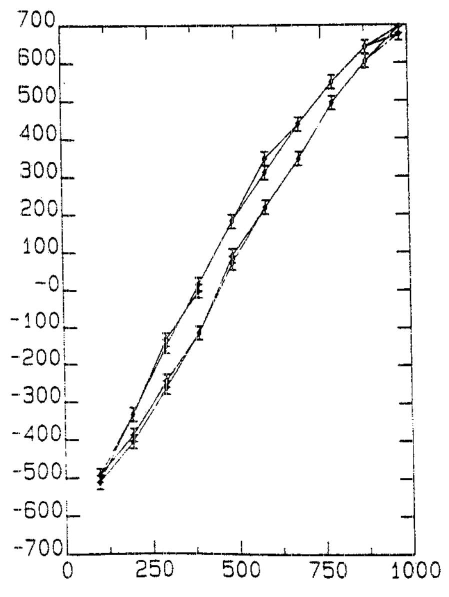

Fig. 3. Laser angular displacement (μrad) as a function of PZT voltage (V).

5. Mirror damage

After the ACO results, it has been evident that one of the major problems for a low gain FEL experiment is the degradation of dielectric mirror reflectivity induced by UV radiation. The high K value of our undulator, and thus the richness of higher harmonics in its spontaneous radiation spectrum, let us foresee this to be the most crucial point of our experiment. For this reason, during the preliminary tests for the alignment of the optical cavity, we analysed the reflectivity of the mirrors exposed to the spontaneous radiation, although during these tests we used commercial grade mirrors.

We measured their reflectivity before the introduction into the cavity by means of the cavity phase shift method and a HeNe laser, finding a reflectivity of 99.8% at 6328 Å. After the exposure, a large decrease of reflectivity has been measured.

A detailed analysis of these results will be presented elsewhere [7]; here we will limit ourselves to show the reflectivity curve of a mirror exposed to 700 mA h of radiation (fig. 4), in which a value as low as 70% is reached. These results show the critical importance of this problem for our experiment. We are now working to reduce this effect in order to keep mirror losses below

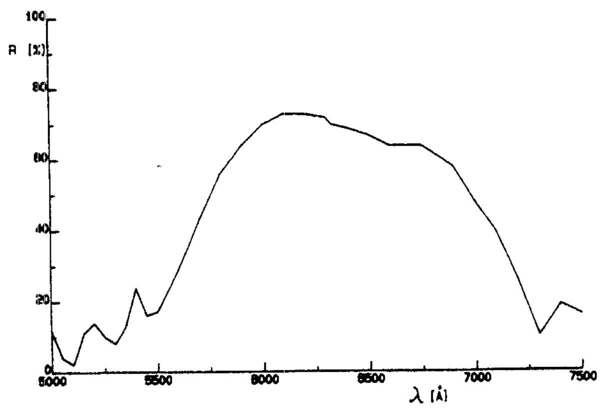

Fig. 4. Reflectivity curve of a mirror exposed to 700 mA h of radiation.

the gain value. The greater part of the damage is due to surface absorption of carbon atoms; so we want to obtain a better vacuum value in the mirror chamber, and to test some protective layers on the mirrors themselves.

References

[1] M. Castellano, N. Cavallo, F. Cevenini, M.R. Masullo, P. Patteri, R. Rinzivillo, S. Solimeno and A. Cutolo, Nuovo Cimento 81B (1984) 67.
[2] R. Barbini et al., J. de Phys. 44, C1 (1983) 1.
[3] M. Biagini et al., SPIE vol. 453 (1985) p. 275.
[4] M. Biagini et al., Nucl. Instr. and Meth. A237 (1985) 237.
[5] M. Ambrosio, G.C. Barbarino, M. Castellano, N. Cavallo, F. Cevenini, A. Cutolo, M.R. Masullo, P. Patteri, R. Rinzivillo and S. Solimeno, Frascati Rep. INFN/TC-84/9 (1984).
[6] M. Ambrosio, G.C. Barbarino, M. Castellano, N. Cavallo, F. Cevenini, M.R. Masullo, E. Gianfelice, P. Patteri, M. Preger and A. Cutolo, 7th Int. Conf. on FEL, Tahoe City, CA (1985).
[7] M. Ambrosio, G.C. Barbarino, M. Castellano, N. Cavallo, F. Cevenini, M.R. Masullo and P. Patteri, 7th Int. Conf. on FEL, Tahoe City, CA (1985).