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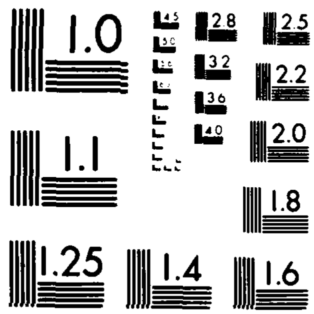

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P. Elleaume, D.A.G. Deacon, M. Billardon, J.M. Ortega

L.U.R.E.

Bâtiment 209C, Université de Paris-Sud

91405 Orsay CÉDEX, France

and

High Energy Physics Laboratory
Stanford University
Stanford, California 94305

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P. ELLEAUME, D.A.G. DEACON, M. BILLARDON, J.M. ORTEGA

LURE
Bâtiment 209C, Université de Paris-Sud
91405 ORSAY Cédex, FRANCE
(Tél. 6.941.82.70)

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P. ELLEAUME, D.A.G. DEACON, M. BILLARDON, J.M. ORTEGA

LURE
Bâtiment 209C, Université de Paris-Sud
91405 ORSAY Cédex, FRANCE
(Tél. 6.941.82.70)

Introduction :

The Orsay free electron laser (FEL) has a round trip gain on the order of several 10^{-4} [1] due to the limited straight section length available on the ACO storage ring and to the available electron density. The oscillation experiment requires the use of extraordinarily low loss mirrors. Much experience exists in the fabrication and measurement of TiO_2/SiO_2 multilayer dielectric mirrors, and the reflectivity which has been obtained at 630 nm (R 99.99 %) is sufficient for oscillation of the FEL. To insure minimum cavity losses (high cavity Q), the mirrors are placed, without windows, in the ultra-high vacuum of the storage ring. Here they have to withstand the strong UV and VUV undulator radiation [2] emitted by a typical current of 100 mA of 150 MeV to 240 MeV electrons.

The Q of the cavity was monitored using two techniques. Both of them measure the cavity decay time of light either emitted from inside the cavity (undulator radiation [1]) or from an external laser [3]. The last method has a signal to noise ratio .5 % and allows reflectivity measurement before insertion into the vacuum and after extraction at the end of the experiment.

Mirror degradation :

The mirror degradation data are summarized in the following table :

Mirror Batch Code	Aδ	2α	B ε	B ε
Loss/mirror in air	$1.3\ 10^{-4}$	$4.5\ 10^{-4}$	$.8\ 10^{-4}$	
Loss/mirror after 10^{-10} Torr pump down	$8.5\ 10^{-4}$	$9.9\ 10^{-4}$	$3.5\ 10^{-4}$	
Average degradation rate/mirror/100 mA electron current/hour	No precise data	$3.2\ 10^{-4}$	$0\pm1\ 10^{-4}$	$20\ 10^{-4}$
Electron energy (MeV)		238	150	230
Undulator flux at fundamental (1.9 eV) (photons/sec/cm^2/mA)		$6.8\ 10^{14}$	$3.1\ 10^{14}$	$5.6\ 10^{14}$
Flux at 3nd harmonic (5.7 eV)		$3.2\ 10^{14}$	$3.7\ 10^{13}$	$2.9\ 10^{14}$
Flux at 5th harmonic (9.5 eV)		$1.7\ 10^{14}$	$5.0\ 10^{12}$	$1.8\ 10^{14}$

Two different degradation mechanisms are identified. The first occurs during the process of pumping down to 10^{-10} Torr but before any light exposure. This process is not yet understood, but is too strong to be explained by the bulk index contribution of water desorbed from the coating layers. Without any synchrotron light exposure, the mirror reflectivity was stable within a precision of 10^{-5} during a 12 hour measurement period and was unchanged after a 75 Roentgen exposure to X ray and gamma radiation generated during the storage ring injection. The second degradation process occurs systematically during light exposure. Since there is no shift in the transmission curve of the mirrors before and after exposure either in wavelength or in magnitude, we conclude that the mirror degradation occurs in either the absorbtion or the scattering channels. The emission spectrum from an undulator has peaks at each harmonic of the fundamental photon energy (1.9 eV in our case) [2]. The flux in each harmonic depends on the energy (see the table). The increase in the B ε degradation rate by a factor of more than twenty from 150 MeV proves that most of the degradation comes from harmonics greater than the 3rd (photon energy > 6eV)

Discussion :

Mirror degradation is a serious problem for the ACO FEL because of the low gain. Similar degradation has been found for the Novosibirsk FEL [4]. The new generation of storage rings optimized for synchroton radiation (Aladdin, Bessy, Brookhaven, Super ACO) should give optical gains on the order of several percent, but their UV fluxes will be significantly higher than on ACO. The solution to the problem may lie in the selection of UV resistant materials for the mirrors, or in a shielding technique with an intracavity Brewster plate or a vapor deposited UV absorber on the mirror surface. We plan to investigate some of these possibilities on the ACO system, but the dimensions of the problem would appear to necessitate a systematic effort if it is to be resolved.

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4. G.N. KULIPANOV
Private communication.

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