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Soft X-Ray Laser Microscopy

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1. Introduction

Microscopes based on soft X-ray lasers possess unique advantages in bridging the gap between high resolution electron microscopy of dehydrated, stained cells and light microscopy at comparatively low resolution of unaltered live cells. The high brightness and short pulse duration of soft X-ray lasers make them ideal for flash imaging of live specimens.

The Princeton soft X-ray laser is based on a magnetically confined laser produced carbon plasma. Radiation cooling after the laser pulse produces rapid recombination which produces a population inversion and high gain. A full account is given in a companion paper in this volume [1]. The important characteristics of the laser beam produced by this device are 1 to 3 mJ of 18.2 nm radiation in a 10 to 30 nsec pulse with a divergence of 5 mrad. The 18.2 nm wavelength, while outside the water window, does provide a factor of 3 difference in absorption coefficients between oxygen and carbon.

2. Status of Microscopy at Princeton

Figure 1 shows a schematic of the Princeton soft X-ray laser experiment. Multichannel XUV spectrometers are normally used to monitor X-ray emission from the plasma. During microscopy experiments the soft X-ray beam is diverted 20 deg. via an astigmatic spectacle lens which serves as a rudimentary toroidal grazing incidence mirror. Figures 2a and 2b give views of the mirror, the positioning system, and the rear portion of the environmental cell. The translators are remotely controlled and allow us to steer the X-ray beam to the environmental cell. The alignment is optimized by temporarily placing a PIN diode detector at the environmental cell position.

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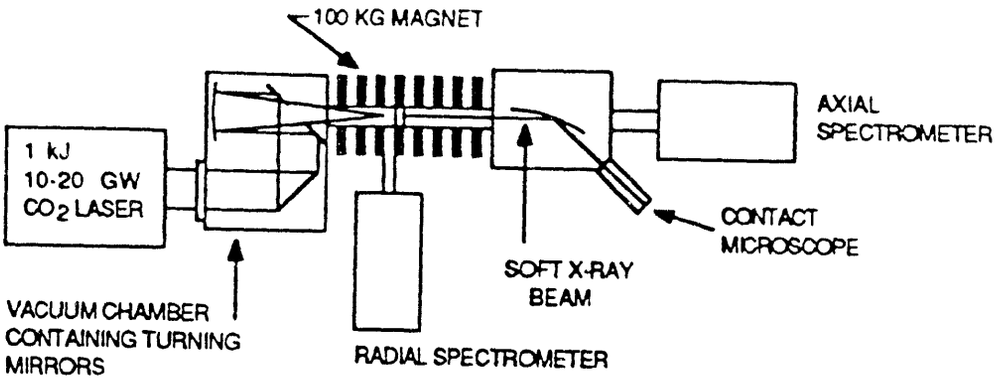

Fig. 1 Schematic of the Princeton Soft X-Ray Laser Experiment

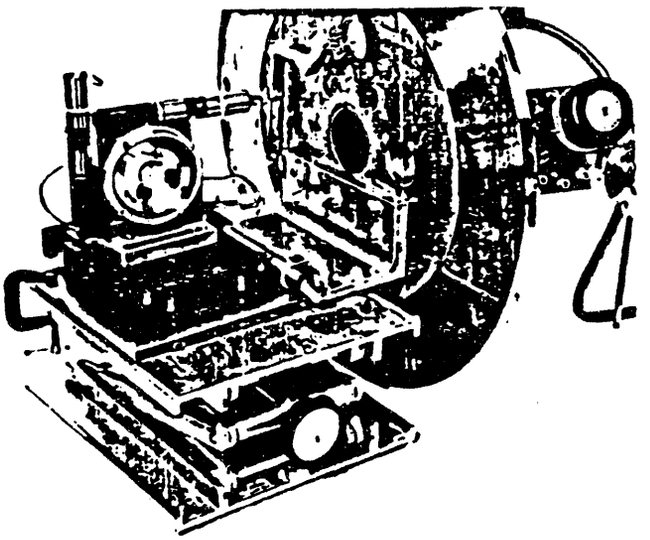

Fig. 2a View of the grazing incidence mirror

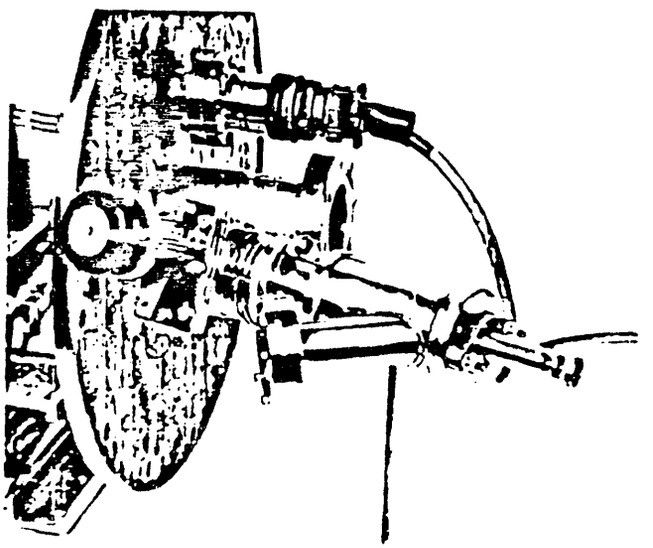

Fig. 2b View of the microscope

Our environmental cell design follows the arrangement used by Feder et al. [2]. A silicon nitride window serves as the vacuum interface. The window is 200 μm x 200 μm x 120 nm thick and is coated with 100 nm of aluminum. The Al acts as a UV rejection filter and also lends some mechanical support to the membrane. Initial experiments have been performed in order to evaluate the performance of the system without the complications involved in handling live specimens. The first of this series used a piece of # 100 wire mesh in place of a living cell. Images of this mesh were recorded on Kodak 101 film and on P(MMA co MAA) resist and may be seen in figs. 3a and 3b.

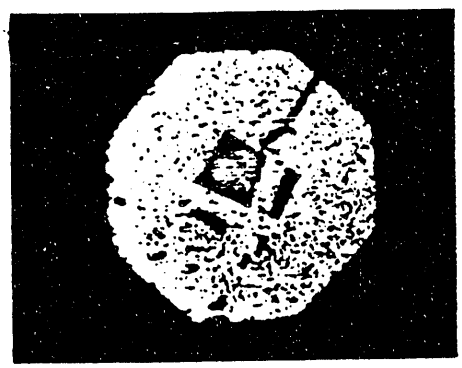

Fig. 3a Image of mesh on Kodak 101 with Si_3N_4 window and Al filter (one laser shot)

Fig. 3b Image of mesh on P(MMA co MAA) (one laser shot)

Each of the above images were generated with one laser shot. They differ only in fact that the resist image was obtained without the use of the aluminum coated silicon nitride window so a contribution from UV light from the plasma cannot be ruled out at this time. The P(MMA co MAA) resist was developed in equal parts of methyl iso-butyl ketone and isopropanol. Images obtained on resist with the window in place were too faint to be clearly identifiable using a metallurgical microscope and an effort is being made to observe these images in an SEM. In the near future the rudimentary grazing incidence mirror will be replaced by a diamond turned ellipsoidal mirror of much superior optical quality. We anticipate a two orders of magnitude increase in soft X-ray intensity at the environmental chamber which should enable the resist to be well exposed.

3. Microscope Development

In future work we plan to use the contact microscope to examine live specimens. The cells will be placed or grown on a suitable resist-coated substrate. This would be brought into contact with the window and exposed with the laser beam. Subsequently, the resist would be ultrasonically cleaned, developed, and examined either by phase or electron microscopy.

In addition a new type of soft X-ray laser microscope, which has already been constructed, will be installed on the soft X-ray laser in the near future. Called COXRALM (Composite Optical X-Ray Laser Microscope), this device is an inverted phase contrast microscope with the capability of observing UV induced fluorescence combined with the option of contact micrograph generation via flash soft X-ray exposure. COXRALM, which is a collaborative effort by Biologists and Physicists, will provide the advantage of being able to observe the specimen up until the time of X-ray exposure. This will directly address the question of specimen condition at exposure and aid in the interpretation of contact micrographs.

Acknowledgements

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