Holographic Interferometry at λ = 3 µm for the Measurement of High Beta Plasma Density Profiles

by
W. Braun
Max-Planck-Institut für Plasmaphysik, Euratom Association, Garching bei München, Germany

Abstract: Holograms are produced using a pulsed HF-Laser. Thin metal films serve as detectors. Sensitivity of the detector is approximately 1 Joule/cm^2, resolution is at least 150 lines/mm. It is planned to use the method described here for density profile measurements in high beta plasmas.

1. Introduction

The electron density profile in a high beta plasma can be determined through the use of interferometric techniques. Since the phase shift is proportional to the wavelength of the laser light and since a toroidal plasma can practically only be optically radiated side-on, the measurements must be carried out in the infra-red regime. The electron density profile of a theta pinch has already been determined by this method using a CO_2-laser with λ = 10.6 µm /1/. This method, however, requires special windows (e.g. BaF_2) on the plasma tube. Holographic interferometry /2/ at $\lambda \approx 3$ µm is a method for measuring the density profile of a high-beta-Plasma which does not require any ports in the quartz tube due to the fact that quartz is still transparent at this wavelength.

2. The 3 µm-Laser

A hydrogen-flouride laser serves as the light source at 3 µm. It is constructed on the same principle as the TEA-CO_2-laser of Beaulieu /3/. The flowing gas is one part H_2 and three parts SF_6 at a total pressure of about 120 torr. A gold plated spherical quartz mirror (radius of curvature R $\approx$ 10m) and a simple plane plate (LiF, CaF_2, or NaCl for example) form the 2.60 m long optical resonator. The gas discharge exciting the laser active molecules is driven by a two stage marx generator bank (2 x 100 nF, U_o = 30 kV). About one thousand resistors (1 kΩ) are spaced in an array so that a gas volume of about 2.50 m x 60 mm x 18 mm is relatively homogeneously excited. The beam cross section is about 15 x 50 mm^2.

The laser pulse is approximately 200 nsec long and was detected by an InAs-diode and a helium cooled Ge:In-crystal. The whole energy in one pulse is about 1 Joule distributed over some spectral lines. Among some of the weaker lines there are three especially strong ones falling in a spectral intervall of about 1/10 µm. It was attempted to distribute the gas discharge even more homogeneously over the whole volume to get a better efficiency per unit vilume, but the principle of the preionized TEA-laser of Dumanchin et al. /4/ led to the same result as Wenzel and Arnold /5/ found. So the efficiency per unit volume could not be significantly increased.

3. Area Detector

High resolution and good sensitivity are needed to make holograms by pulsed exposure at $\lambda \approx 3$ µm. For holographic methods in the visible region with a pulsed Ruby laser thin bismuth films have already been used /6/. In the infrared regime at λ = 10.6 µm (CO_2-laser) films of bismuth, antimony, cadmium and paraffin were used successfully /7/. In the present work metal films of 100 Å thickness of Bi, Sb, Cd and Au and paraffin films were vacuum deposited on several different substrates such as glass and plexiglass. The experimental set up used to investigate these detectors at $\lambda \approx 3$µm is shown in Fig. 1.

A clear recognizable interference fringe pattern could be achieved on an area of about 2 x 20 mm^2 of a 200 Å Bi-film by means of a single exposure. Here, as previously found by Decker, Herold and Röhr /7/, the strong nonlinear characteristic of the Bi-film could also be observed. This characteristic is responsible for the following effect. In double exposure holograms taken at 10.6 µm those parts of the pattern where the metal was completely evaporated during the first exposure, could not record further information. The hologram of a wedge of salt (NaCl), however, could be nicely reconstructed. A resolution of fringe displacements of a tenth of one fringe distance was achievable. As already reported for the λ = 10.6 µm investigations it is rather difficult to find the right relationship between laser energy density and the metallic film thickness. A large area exposure of the Bi-films gives rise to further difficulties. The steep gradation necessitates a very homogeneous distribution of the laser light power over the beam cross section.

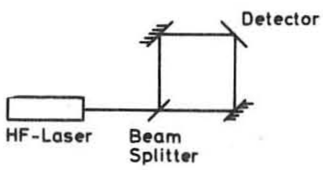

Fig. 1

It is planned to use the method described here for density measurements in high beta plasmas.

/1/ Z. Physik 248, 121 (1971)
/2/ Appl. Optics 6, p. 1407 (1967)
/3/ Appl. Phys. Lett. 16, p. 504 (1970)
/4/ R. Dumanchin et al., Int. Quantum Electronics Conf., Kyoto, (1970)
/5/ IEEE, Vol. QE-8, p. 26
/6/ Appl. Phys. Lett. 15, p. 45 (1969)
/7/ G.Decker, H.Herold, H.Röhr; J. Opt. Soc. Am., to be published