JOINT EUROPEAN TORUS

JET–P(93)50

G. Magyar and J. O'Rourke

Depolarization of Far Infrared Laser Beams in Inconel and Alumina Waveguides

Depolarization of Far Infrared Laser Beams in Inconel and Alumina Waveguides

G. Magyar and J. O’Rourke

JET-Joint Undertaking, Culham Science Centre, OX14 3DB, Abingdon, UK

Preprint of a paper to be submitted for publication in
Infrared Physics

Far infrared interferometric systems on large tokamaks like JET require beam propagation over long distances (~ 80m on JET) with minimum loss. It was shown in [1] that at 339 μm wavelength of the HCN laser oversize waveguides of the dialectic type (glass) are more efficient than metal (copper) waveguides.

In fact the attenuation constants for the EH_{11} and TE_{11} (linearly polarized) mode - the only mode of interest in this application - are:

$$\text{(dielectric)} \quad \alpha_{EH_{11}} = K \frac{\lambda^2}{D^3} \frac{\upsilon^2 + 1}{\left(\upsilon^2 - 1\right)^{1/2}}$$

$$\text{(metal)} \quad \alpha_{TE_{11}} = K' \frac{1}{D} \frac{1}{(\sigma\lambda)^{1/2}}$$

where K and K′ are constants, λ is the wavelength, D the inner diameter of the guide, ν the refractive index.

However, the interferometric set-up is sometimes also utilised for a second measurement, that of the Faraday Effect from which the poloidal magnetic field may be deduced [2]. In this case the degradation of polarization in the waveguide becomes also an important criterion. The problem was investigated and reported in [3]. It was found that polarization is much better preserved by glass than by copper waveguides (77% versus 19% for incidence parallel to the axis of a 30 m tube. The diameters were different: glass - 40 mm, copper - 70 mm). Furthermore, polarization degrades with increased angle of incidence for both types of waveguides but the effect is greater for copper (~ 50% at 15 mrad incidence angle) than for glass (~ 10%), both as a percentage of the 0 mrad case.

On this basis the JET polari-interferometric system has successfully used a ~ 30 m long Pyrex glass waveguide system (diameter ~ 80 mm) for the return path of the 195 μm laser beams [4].

In connection with the re-structuring of the JET machine it has become necessary to use a re-entrant inconel tube, 1.4 m long, 41 mm inner diameter for the input and output probing beams of the polari-interferometer. This has posed again the question of possible depolarization of the Faraday rotated laser beams.

In case of serious problems the alternative of coating the inner surface of the tubes with a dielectric layer was considered. Due to the small diameter this was not feasible technically. The coating of a thin metal liner was tested; unfortunately the foil became distorted in the coating process. Finally a thin-walled (~ 2.0 mm) $A\ell_2O_3$ ('alumina') tube was fabricated as an insert into the metal tube.

An experiment was set up to compare the depolarization properties of the two waveguides as shown in Fig. 1. The 195 μm radiation of the DCN laser was cleaned up by grid polarisers, passed through the inconel or alumina waveguide and detected by either a calorimeter or a pyroelectric (TGS) crystal. The latter required the modulation of the beam amplitude.

First the beam was detected without the waveguide, its value noted and then a crossed polarizer was adjusted for minimum transmission. The percentage depolarization was calculated as the ratio of the latter to the former. Then the waveguide was interposed and the amount of depolarization noted. The latter was done both with the waveguide axis aligned with the direction of propagation and a misalignment of ~ 7 mrads.

The experiment was carried out in a dry air enclosure to eliminate absorption by air humidity. The detectors were either close to the end of the waveguide or at a distance of ~ 2.5 m. The results, tabulated below, are reported for the latter case which is more relevant for the final application.

Table 1

	Depolarization (%)	
Medium	**Calorimeter**	**Pyroelectric cr.**
No waveguide	0.47	0.42
Inconel waveguide, 1.4 m	3.7	2.0
Alumina waveguide, 1.4 m	0.5	0.5
Inconel waveguide, 1.4 m, misaligned	5.5	1.1
Alumina waveguide, 1.4 m, misaligned	0.4	0.48

The instrumental errors are ± 10%. However, the alignment of the waveguide is critical and this produces some additional errors. Nevertheless the trend is clear from the table.

The results show that the depolarization due to inconel is much less than it would be due to copper. This is understandable if one takes into account the worse electrical resistivity of inconel (103 microhm cm as against that of copper with 1.3). The calorimeter result is more pessimistic, presumably because it collects some scattered light and integrates it. The misalignment increases it while reducing the transmitted intensity. The contribution to the total error in a polarimetric measurement would be small, but not negligible.

The difference between the calorimetric and pyroelectric detectors is reduced when they are further removed, e.g. doubling the distance to ~ 5 m the depolarization became 2.4 and 1.8%, respectively. Reducing the length of the inconel waveguide - covering the exit side with 70 cm alumina tube - reduced the depolarization, showing that the effect is approximately proportional to length.

The alumina waveguide is clearly superior. The depolarization is only ~ 0.5%, practically the same as without the waveguide. Even misalignment does not influence it significantly but only causes the expected loss of intensity. The two methods of measurements also agree better than for the metal waveguide.

REFERENCES

[1] Crenn, J.P., **IEEE MTT-27, 6,** 573 (1979)

[2] Soltwisch, H. and Equipe TFR, **Infrared Physics, 21,** 287 (1981)

[3] Véron, D., Course on Diagnostics for Fusion Reactor Conditions, Varenna, September 1982, CEC Brussels, EUR 8351-IEN, **Vol. 1,** 199 (1982)

[4] Braithwaite, G., Gottardi, N., Magyar, G., O'Rourke, J., Ryan, J and Véron, D., **Rev. Sci. Instrum., 60,** 2825 (1989)

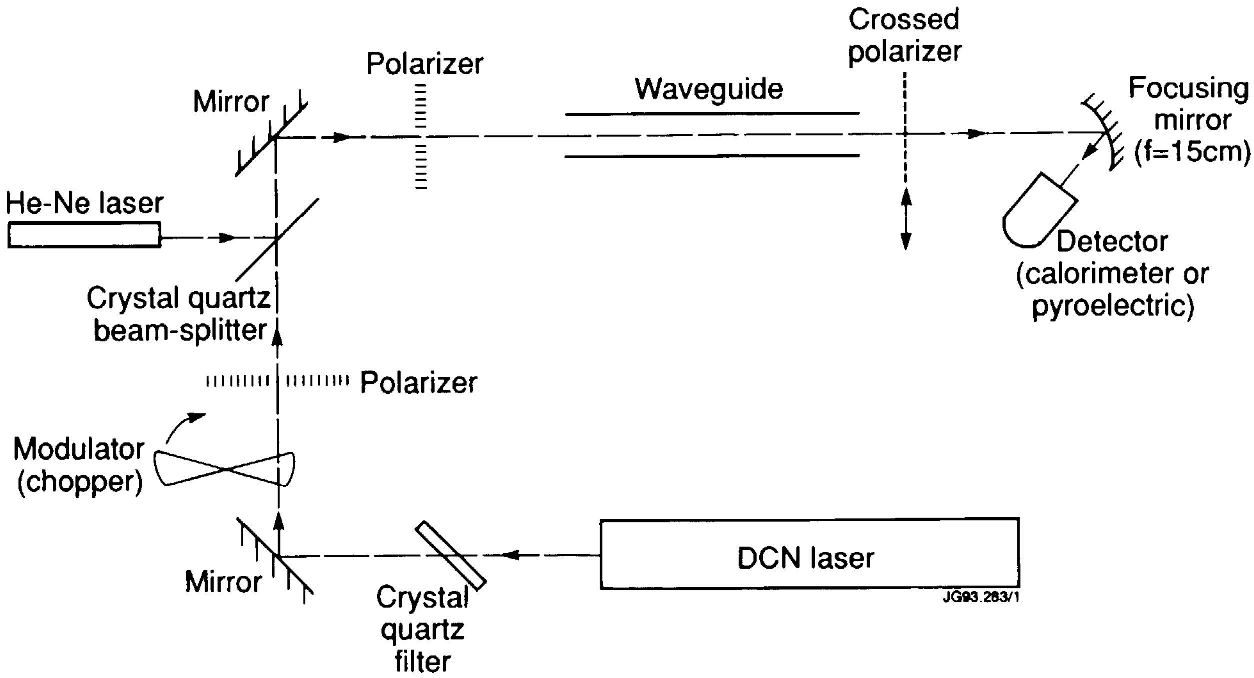

Fig. 1 Experimental arrangement