FIR LASER SCATTERING AND HETERODYNE RECEIVER MEASUREMENTS ON ALCATOR C

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Introduction

The MIT program to develop high power collective Thomson scattering diagnostics will be presented.

All elements of a 385μ D_2O laser Thomson scattering diagnostic are in place and operational on the Alcator C tokamak. Major components include: a 0.5 MW, 150 ns D_2O laser; a heterodyne receiver mixer and a 25 MW, 381μ DCOOD laser local oscilator; and X-band I.F. electronics including a 32 channel multiplexer filter centered at 9.4 GHz with 80 MHz wide channels. Receiver noise temperatures (not including signal collection optics) of 15,000 - 20,000 K double sideband (DSB) have been measured for individual filter channels. Additional details of the D_2O laser, the receiver and the overall implementation of this diagnostic on Alcator C have been described previously [1-3].

The scattering geometry is shown in Figure 1. The scattering angle is 18° from a plasma volume located 7 cm from plasma center. This scattering arrangement was determined by the diagnostic port access of Alcator C. The port access is very constrained. The D_2O laser beam and the reciever field of view must traverse slots in the stainless steel flange which have a width of only 2.5 cm and a depth of about 28 cm.

Scattering Measurements

Initial scattering measurements show high levels of stray D_2O laser power. The spectrum of the stray light is shown in Figure 2. This spectrum is for a single laser shot measurement obtained by operating the Thomson scattering diagnostic with no plasma in the tokamak. A stack of

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paper attenuators equal to approximately 44 db attenuation was used in front of the receiver to obtain an on-scale spectrum The laser linewidth at half maximum is less than one channel wide (80 MHz).

Initial work with narrow band filters to reject the stray light have been partially successful. The most successful has been an X-band notch filter which was placed after the Schottky diode mixer to reject a 240 MHz band centered at 9.4 GHz. Stray light levels were reduced by 16 to 20 dB, significantly short of the ~ 40 dB attenuation required. An optical Fox-Smith is also being developed as a receiver front end.

Detailed measurements of the propagation and focusing of the D_2O laser beam and the receiver field of view into the beam and viewing dumps respectively, show that the high level of stray light is due to beam clipping and diffraction caused by the diagnostic slots. Both input and output beams are focusing more poorly than expected for fundamental mode Gaussian beams. Optics of F-number 15, minimum, are required to access the Alcator C plasma through the diagnostic slots. The focused $1/e^2$ spot size of the D_2O laser beam was measured to be elliptical with diameters of 2.3 and 2.8 cm in the two orthogonal dimensions. The receiver field of view could only be focused to a 3.4 cm spot size. The size of these beams at the input of the slots is even larger. As a result, up to 20% of the D_2O laser beam and as much as 50% of the receiver field of view may be clipped.

Plasma ($n_e > 10^{14}cm^{-3}$) scattering measurements were attempted with the above levels of stray light and 20 - 30 dB attenuation in front of the receiver to prevent I.F. amplifier saturation. No evidence of intense nonthermal scattering was observed at these levels.

Recently, a gas filled cell has been placed between the tokamak scattered light port and the heterodyne receiver in order to reduce the level of stray light entering the receiver. The cell is filled with N_2O gas which has an absorption line at 778.18 GHz, the J = 30 to 31 transition in the ground state. The D_2O laser is tuned, by tuning the CO_2 pump laser, so that D_2O laser emission is centered at 778.18 GHz. The tunable D_2O laser operates with optimum efficiency at about that frequency. The purpose of the gas cell is to absorb stray light from the D_2O laser which is unshifted in frequency, while transmitting light Thompson scattered from the plasma which is shifted by more than about 200 MHz. The gas cell can be varied in both length and pressure. The line center absorption coefficient of the N_2O gas transition has been calculated to be 0.0237 cm^{-1} and this value has been verified experimentally. The pressure broadening coefficient is 8.4 MHz/Torr. For a N_2O gas cell about 6m long, the reduction factor for stray light is about 60 dB. If the same gas cell is operated at 8 Torr, with an absorption half-width of 67 MHz, the absorption factor for Thomson scattered light offset in frequency by 300 MHz is only 3 dB. The performance of the gas cell should be far superior to that obtainable with conventional optical filters such as Fabay-Perot interferometers. A gas cell is now in place on the Alcator C scattering system and will be used in new studies of Thomson scattering. The gas cell is also useful for studies of the frequency distribution of the incident D_2O laser radiation.

ECE Measurements

The heterodyne receiver has been operated alone to monitor the background electron cyclotron emission (ECE) at 787 $\pm$ 10 GHz. The full 5.5 GHz DSB of the receiver and 1 msec integration times were used for these measurements. The background ECE levels are of the same order as previously measured on Alcator A [4,5] for corresponding magnetic fields. In Figure 3, the middle trace shows the ECE signal from Alcator C for a magnetic field on axis of 8 Tesla, $n_e = 2.8 \times 10^{14} cm^{-3}$, and I_p = 380 kA in a hydrogen plasma. At this magnetic field, fourth harmonic emission is located ~ 9 cm from the plasma center within the direct field of view of the receiver. In addition, third harmonic emission from the inside of the torus may be finding a reflective path to the receiver. The peak ECE signal in Figure 3, 300 msec into the discharge, is 2.4×10^{-19} WHz^{-1} at the crystal quartz window (calibration described in [5]). This is far below the expected Thomson scattering thermal feature.

Conclusions and Future Work

The D_2O laser Thomson scattering system is operational on Alcator C. High levels of stray light due to very constrained port access, and laser beam and receiver focusing difficulties, is preventing the measurement of the thermal feature. Other sources of background noise such as strong non-thermal scattering and ECE do not appear to be a problem.

Work is underway to improve the transverse mode quality of the laser and receiver to improve matching to the beam and viewing dumps. In addition, wider bandwidth I.F. notch filters will be employed and attempts will be made to further improve the frequency quality of the D_2O laser Scattering at a larger angle would also reduce the stray light problem because the scattered spectrum will be of a wider bandwidth, allowing the use of wider notch filters. Scattering from thermal fluctuations at a plasma resonance such as the lower hybrid frequency will also be attempted. The lower hybrid frequency is 2 to 5 GHz from D_2O line center where stray light effects should not be a problem.

A general assessment is also being made of the advantages for collective Thomson scattering by advanced submillimeter/millimeter sources such as gyrotrons, both rapidly pulsed and cw, and rapidly pulsed lasers. These sources could provide significant improvements in signal-to-noise ratios over the single pulse, high power lasers. These improvements would result from the increased signal sampling times, the potential for optimizing peak power/average power tradeoffs and the capability with gyrotrons of operation at very high average power levels.

References

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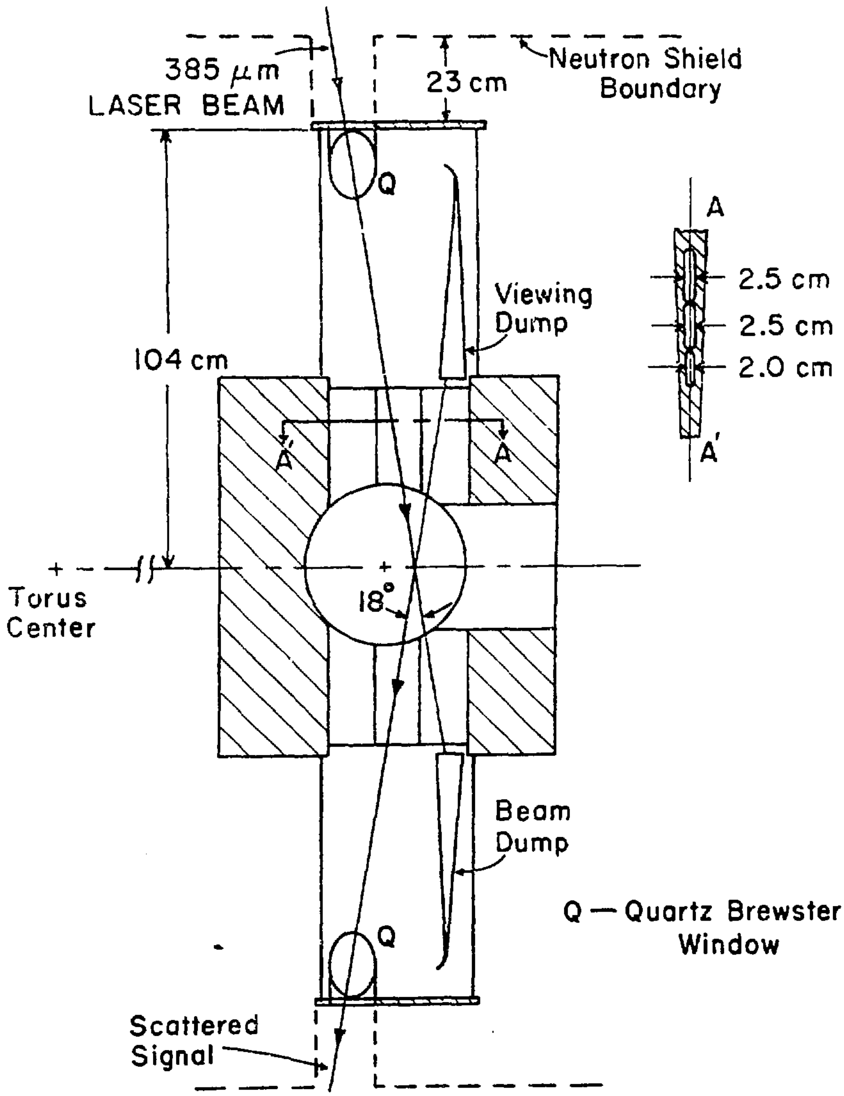

Fig 1. Cross-sectional view of Alcator C showing scattering geometry. Section A-A shows the top view of the diagnostic slots.

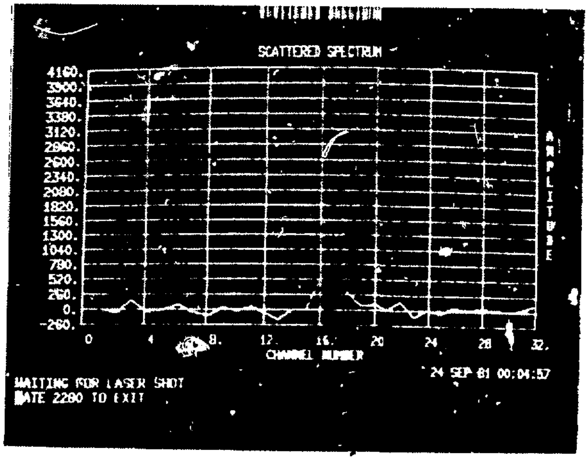

Fig 2: Stray D_2O laser power with 44 dB attenuation at receiver. Each channel is 80 MHz wide.

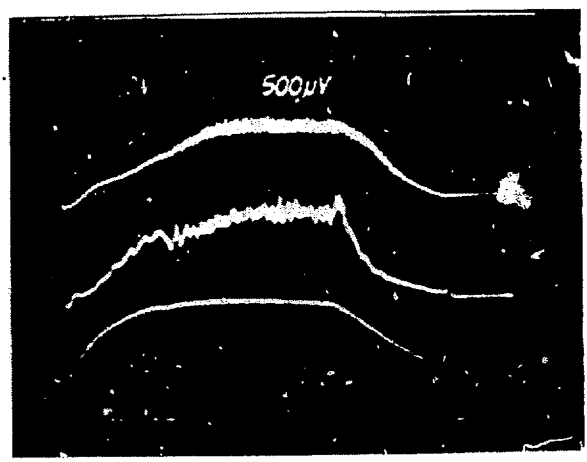

Fig. 3: Data from one Alcator C discharge at a toroidal field of 8 Tesla. Time scale is 50 ms per division.