USA-Japan Workshop on Sub-Millimeter
Diagnostic Techniques, Jan. 18-21, 1982
Institute of Plasma Physics, Nagoya University
Nagoya, Japan

Development of High-Power Optically-Pumped Far-Infrared Lasers for Plasma Diagnostics

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Abstract

The activities for developing an over 0.1-MW optically-pumped 385-μm D_2O laser and a CW optically-pumped 382.9-μm CH_2F_2 laser as local oscillator for measurement of ion temperature in Tokamaks are described.

I. Introduction

We are developing a high-power (over 0.1 MW) optically-pumped 385-μm D_2O laser system for measurement of the ion temperature in Tokamaks. In 1980, a single-mode 9R(22) TEA CO_2 laser oscillator was completed. In the 1981 fiscal year, two TEA CO_2 laser amplifiers will be constructed and operated. High-power optically-pumped 385-μm D_2O laser will be designed and constructed in the 1982 fiscal year.

This paper will describe our activities for developing the high-power optically-pumped pulsed and CW far-infrared (FIR) lasers for measurement of the ion temperature in Tokamaks through Thomson scattering.

II. Development of an optically-pumped 385-μm D_2O laser for measurement of the ion temperature

2.1 Present status

We have three Lumonics TEA CO_2 lasers as a tunable single-mode 9R(22) CO_2 laser oscillator (K-921s type, in 1980), first double-pass CO_2 laser amplifier (K-922s type, in 1981) and second triple-pass CO_2 laser amplifier (601A type, in 1981). The details of our TEA CO_2 laser system have been described elsewhere [1]. The 0.1-J, 100-ns 9R(22) TEA CO_2 laser oscillator output will be amplified by passing through the two amplifiers. Over 10-J, 100-ns output is expected from this CO_2 laser system. The output will be used to pump the D_2O vapour in the 100-mm I.D., 4~5-m long glass tube. The 385-μm D_2O laser will be composed of NaCl input window, crystal-quartz beam splitter, grating reflector, Fox-Smith mode selector, teflon pump-beam dumper, metal mesh output coupler and polyethylene output window. According to the MIT scaling law [2], we can expect over 0.1-MW output at 385 μm, which shall be completed by March 1983.

The lasing frequency of D_2O Raman laser at 385 μm will be measured using a metal-mesh Fabry-Perot interferometer. The evolution of the pulsed output at 385 μm will be measured using a Schottky-barrier diode in an electromagnetically shielded room.

2.2 Future plans

In order to increase the output energy of the tunable TEA CO_2 laser oscillator, we try a folded unidirectional ring cavity [3] to avoid exposing the ZnSe etalon to damaging power level of about 0.1 J. The folded ring TEA CO_2

laser cavity has a total round trip length of about 3 m. We expect a total energy output of 0.5 to 1 J for the 9R(22) line, and a tuning range of ± 1 GHz off line center. This results in a final energy-output amplified of 20 to 30 J.

Three spatial filters are used in our TEA CO_2 laser oscillator-amplifier system. In general, imaging elements such as spatial filter are required in a laser chain to control the divergence and diameter of a laser beam as it is intensified [4]. The purpose of image relaying by means of the spatial filter is to maintain a high fill factor by imaging one laser aperture to the next and to protect optical material from damage by suppressing the diffraction rings. Such a clean pump beam in turn will generate a clean Gaussian intensity profile at 385 μm which can be focused into a small spot in the Tokamak plasma.

The thickness of crystal-quartz beam splitter will be finely adjusted [5] in order to increase Q-values of the Fox-Smith mode selector and to get a single longitudinal-mode oscillation at 385 μm.

Since we have some experiences on the stable CW twin optically-pumped 118.8-μm CH_3OH laser [6], a CW stable high-power 382.9-μm CH_2F_2 laser [7] will be constructed as a local oscillator.

III. Fast plasma detector

We have developed a fast plasma detector [8] to monitor the time evolution of pulsed output from the TEA CO_2 laser system.

Principles of operation of the plasma detector are summarized shortly as follows. We can observe voltage on an isolated laser-irradiated metal target. The voltage results from high-energy electrons leaving the laser-produced plasma and going a distance (0.5 mm) where they strike the metal aperture having 0.5-mm pinhole. The high-energy electrons can rapidly move through a return circuit to the target region, where they will recombine the ions with slower speeds near the target. Useful voltage can be generated by inserting a resistive element of 50 Ω in the return circuit.

Features of the plasma detector developed [9] are as follows ; (1) it operates at room temperatures, (2) has a rise time shorter than 400 ps, (3) generates larger output signals than a photon-drag detector, (4) is cheap, and (5) may be in principle strong against X-rays, γ-rays and neutrons. Therefore, the plasma detector has performances over photon-drag detector and fast pyroelectric detector.

Using the plasma detector developed [9], a single longitudinal mode operation was easily and reproducibly observed for our TEA CO_2 laser oscillator where a 2-cm long ZnSe etalon having 60% reflection coating on both sides was inserted into the 1.4-m long cavity.

IV. Doppler-free optoacoustic spectroscopy

In the course of developing CW optically-pumped FIR lasers as local oscillator, the knowledge on the precise pump offset frequency with respect to pump CO_2 laser line center is very important to get a stable and high-power (>50 mW) CW FIR laser output.

The pump offset frequencies of CH_2F_2 and CH_3OH FIR lasants with respect to the line center of CO_2 laser have been measured by means of Doppler-free optoacoustic spectroscopy [7]. When the CW CO_2 laser was tuned to the 9P(10) line, the Doppler-free optoacoustic spectrum of CH_2F_2 showed a sharp absorption line at the offset frequency of +2 ±2 MHz, which was good agreement with the offset frequency of +9 ±4 MHz obtained through the CW 382.9-μm lasing [7].

This information on the pump offset frequency will be useful when constructing a CW optically-pumped 382.9-μm CH_2F_2 laser as a stable high-power local oscillator (here note that the 382.9-μm line is about 4 GHz apart from the 385-μm line of D_2O laser).

V. Conclusion

We are having sufficient techniques for constructing an over 0.1-MW 385-μm D_2O laser with clean beam and a CW stable FIR local oscillator for measurement of the ion temperature in Tokamaks. Such D_2O laser shall be completed by March 1983.

This work was supported in part by the Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture, Japan.

References

[1] M.Yamanaka : Summary of Japan-USA Workshop on Far Infrared Diagnostics, Jan. 28-31, 1980, MIT, Cambridge, USA, No. 10.

[2] P.Woskoboinikow : Private communication (1979).

[3] P.Bernard et al. : Opt. Comm. 37 (1981) 285.

[4] J.F.Holzrichter : "High-Power Pulsed Laser" in Laser-Plasma Interaction, eds. R.A.Cairns and J.J.Sanderson, SUSSP Publications (1980) p.497.

[5] A.Nishizawa et al. : 6th Int. Conf. IR MM Waves, Dec. 7-12, 1981, Miami, USA, Conf. Dig., No. M-3-9.

[6] M.Yamanaka et al. : Int. J. IR MM Waves 1 (1980) 57.

[7] Y.Tsunawaki et al. : 6th Int. Conf. IR MM Waves, Dec. 7-12, 1981, Miami, USA, Conf. Dig., No. F-4-4.

[8] E.E.Bergmann et al. : Appl. Phys. Lett. 37 (1980) 18.

[9] M.Yamanaka et al. : Second Annual Meeting of The Laser Society of Japan, Jan. 21-22, 1982, Riken, Tokyo, Digest of Technical Papers, No. 22 a-I-11.