Diode-pumped Terahertz laser source based on stimulated polariton scattering

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Terahertz (THz) radiation has been referred to as the "last frontier of the electromagnetic spectrum" because it is one of the most difficult frequency bands to generate and detect. While the potential for THz radiation to be used in medicine, biology, security and other applications has been abundantly demonstrated [1], the widespread uptake of THz technologies is hampered by the need for practical, low-cost THz sources. Terahertz parametric oscillators (TPOs) make use of both second and third-order nonlinear processes ie optical parametric oscillation and stimulated Polariton scattering respectively [2] and are a promising solution to this problem. Recently Edwards et al [3] demonstrated a diode-pumped intracavity TPO which generated tunable, pulsed (10 ns) THz radiation, with average powers up to 10 μW. Here we report on a system with similar overall architecture, but make use of CW diode pumping and a resonator design which provides higher cavity Q together with smaller mode size in the active crystals. The attractive features of this diode-pumped, intracavity TPO include its very low threshold (corresponding to 3.8 W diode pump power), together with its relative simplicity, compactness and the robust, cost-effective Nd solid-state laser technology on which it is based.

The layout of the intracavity TPO is shown in Figure 1. A Nd:YAG rod (5mm diameter, 5mm length) is pumped with a fibre-coupled, continuous-wave 30-W, 808-nm laser diode and generates fundamental emission at 1064 nm. This is the pump field for the parametric interaction. The Q-switch generates high intracavity powers, within the 50 mm long nonlinear crystal (5% MgO: $LiNbO_3$) which is located within the cavity of the Nd laser in order to access the high circulating powers. A wave vector diagram showing the pump (fundamental), idler (near-infrared) and signal (THz) fields is shown in Fig 1. The idler is resonated between two high reflectivity mirrors along an axis oriented a few degrees from that of the fundamental beam. These two infrared beams interact with the nonlinear crystal to produce the THz radiation (signal wave), which propagates towards the side of the nonlinear crystal. Due to the complexities of detection and extraction of THz radiation [3], our initial work has involved investigating the performance of the idler (near-ir), and used conservation of energy and photon numbers in order to predict the wavelength and power of the THz radiation being generated.

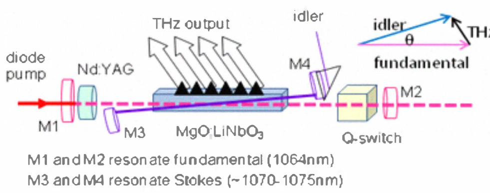

Figure 1 : Experimental setup

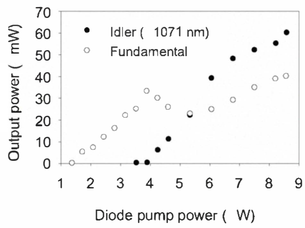

Figure 2 : Power characteristics

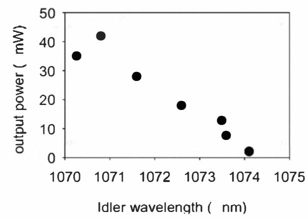

Figure 3 : Power vs wavelength

Fig 2 shows the output power at the fundamental (through M2) and the idler (through M4) as a function of input pump power. Threshold for the polariton laser occurred for just 3.8 W from the pump diode. The corresponding peak intracavity power for the fundamental at 1064nm was 50 $MWcm^{-2}$. Depletion of the fundamental above this threshold is also apparent. By changing the angle between the idler and fundamental cavities, the idler wavelength could be tuned from 1070.3 to 1074.6 nm. Fig 3 shows the output power as a function of wavelength. This corresponds to a THz frequency range of 1.66 to 2.8 THz. By considering photon numbers, we predict the average power for THz radiation generated was ~900 μW. We measured the idler pulse to be ~20 ns duration. We investigated the degree to which the fundamental was depleted first by comparing the fundamental output through M2 when the idler cavity was blocked/unblocked, and also by recording oscilloscope traces of the pulse shapes when the resonator was blocked/unblocked. In both cases the pump depletion was found to be around 40%.

In conclusion we have demonstrated a diode-pumped THz laser with very low (3.8 W) diode pump threshold. We have studied the idler properties of our intracavity TPO and predicted the properties of the THz radiation generated in the $MgO:LiNbO_3$. Our ongoing work is to use silicon prisms, as in [2,3] to couple out the THz radiation, and enable direct measurements of the extracted THz radiation.

References

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