than the slope at high frequencies, with a transition near 1 kHz. A comparison of this work with the work of other authors[3-7] (who used different measurement techniques) showed that this slope change is real. The low frequency slope in Fig. 1 is −3 dB/octave; the high frequency slope is 6 dB/octave. This result was unexpected; thermal filtering of the pump fluctuations seemed a likely cause. A theoretical model was developed from this assumption and agreement was obtained (Fig. 2) with the observed frequency dependence.

Finally, as an extension of our earlier work[8] and as a demonstration of the frequency stability of these lasers, 2 NPROs were locked to adjacent axial modes of a high-finesse interferometer, and relative stability at the subhertz level was achieved (Fig. 3). This locking was accomplished by using interferometers with transmission passbands as low as 25 kHz, control electronics with gains less than 125 dB, and bandwidths below 100 kHz.

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11:30 am

CME5 Polarization switching of microchip lasers

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We constructed a polarization-switchable microchip laser from a cw 1.064-μm Nd:YAG microchip laser[1] a piece of $LiTaO_3$, and a discrete, flat, partially reflecting mirror, as shown in Fig. 1. The cw microchip laser consisted of a 650-μm-long piece of 1.3-wt.% Nd:YAG with two flat mirrors (a pump mirror and a partially reflecting output mirror). The discrete partially reflecting mirror was mounted on the $LiTaO_3$ and held parallel to the mirrors of the cw microchip laser, with the $LiTaO_3$ toward the cw device. Electrical contacts were deposited on the $LiTaO_3$ to allow electro-optic control of its optical length. The partially reflecting output mirror of the cw microchip laser, the $LiTaO_3$, and the discrete partially reflecting mirror formed a birefringent tunable étalon. The two orthogonal polarizations of the étalon see a low-Q cavity at different times across its free spectral range. As a result, application of the proper voltages to the $LiTaO_3$ allowed switching of the laser between the two polarizations.

With proper biasing of $LiTaO_3$, a 200-V change completely switched the laser's polarization. As shown in Fig. 2, the switching took place in < 5 μs, faster than the time required for the driving voltage to switch between its high and low state. The slew rate of the driving voltage may be a limiting factor.

Earlier work[2] indicates that the time required for a laser to switch between two modes is approximately given by the cavity lifetime divided by the gain differential between the two modes. The cavity lifetime of the microchip laser is typically < 1 ns, which suggests that much faster polarization switching should be obtainable. Because the laser is always oscillating in one of the two polarization states, except for the short amount of time required to switch polarizations, the inversion of the laser is always clamped at its threshold value, and there is no significant relaxation spiking when the laser is switched between states.

A binary data stream can be used to control the polarization of a polarization-switchable microchip laser. Digital information can be recovered by passing the output of the laser through a polarizer. If sufficiently fast polarization switching can be obtained, polarization-switchable microchip lasers may find applications in optical communications.

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11:45 am

CME6 A high-efficiency, laser-diode-pumped continuous wave miniature Nd:glass laser

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The laser-diode-pumped, actively mode-locked Nd:glass laser has recently been shown to be a good source of picosecond pulses.[1,2] Subpicosecond pulses have been obtained by using self-starting additive pulse mode-locking (APM),[3] where the Nd:glass laser was pumped with a krypton laser.[4] An intensity threshold for the onset of self-starting APM[5] indicates the need to develop high-power, high-slope efficiency, laser-diode-pumped Nd:glass lasers, if self-starting APM is to be achieved in this all solid-state system.

We have pumped an Nd:glass laser with a single-stripe 500-mW laser diode yielding an output power of greater than 100 mW, at a slope efficiency of 30%. Double-end-pumping with two such diode lasers, produced an output power greater than 150 mW. Our pump lasers were 40-μm broad-stripe devices (STC,LQ05-78), temperature-tuned to ensure high absorption (95%) in the Nd:glass.

A standard three-mirror, astigmatically compensating cavity was used, with an output coupling of 1.5%. The active medium was a 1.2-mm-thick, 10-mm-diameter disc of Schott LG760 glass with 8% wt.Nd^{3+} doping, placed in the cavity at Brewster's angle. The glass was held between two copper plates; a 100-μm layer of indium between the glass and the copper produced good thermal contact to ensure good heat sinking, thus reducing the effects of thermally induced birefringence.

When the laser was pumped through the cavity rear mirror with one diode laser, a 3.2-cm lens focused the pump beam. The observed threshold and slope efficiency were 63 mW (absorbed pump power) and 30%, respectively. This slope efficiency represents a significant improvement over previous values[1,2] typically of 12% for the laser-diode-pumped Nd:glass laser, where laser-diode arrays served as the pump source. The maximum output power from this laser was 101 mW for 450 mW absorbed pump power.

When two such laser diodes were polarization coupled to pump the Nd:glass laser, the glass melted at a combined pump power of approximately 600 mW. To overcome this problem and to produce a more uniform longitudinal temperature distribution, we double end pumped the Nd:glass laser by using a second diode laser (diode 2) to pump the glass disc through the cavity turning mirror. The beam from diode 2 had to be expanded by using an X2 telescope to ensure that the Nd:glass laser operated in the TEM_{00} mode when pumped with diode 2 alone. The pump beam was focused with a 7.5-cm lens. The maximum power incident on the glass from this diode was 350 mW (because of aperturing of the expanded beam); the maximum output power obtained was 43 mW. When pumped simultaneously with both diodes, the maximum output power from the Nd:glass laser was 153 mW, but improving the design of the focusing geometry for diode 2 should increase this power to more than 180 mW.

Detailed performance characteristics of this laser will be discussed, along with the problems caused by thermal effects in the active medium. We will also report on our experiments to increase the output power from this laser and the self-starting modelocking of the diode-pumped Nd:glass laser.

**Also with the Opto-Electronic Research Centre, University of Southampton*

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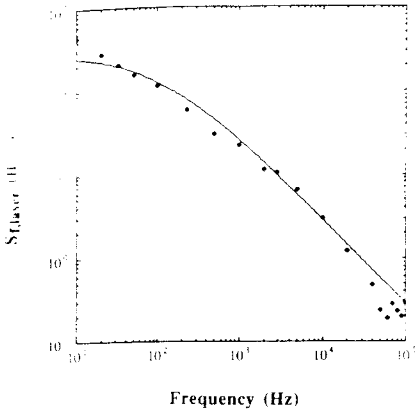
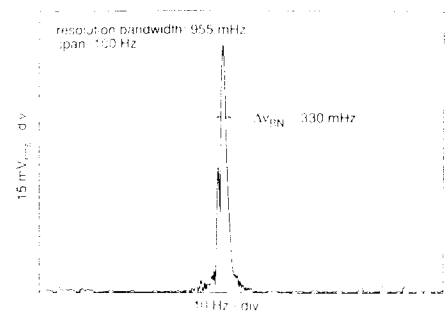
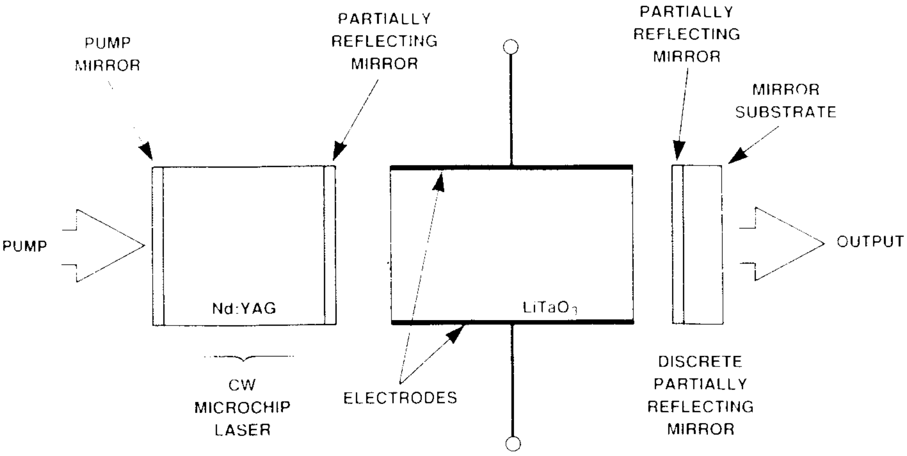


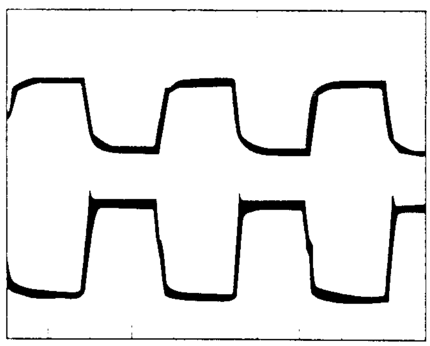
... 2. The theoretical frequency dependence of the spectral density of frequency noise ... plotted together with the data of Fig. 1. ... theoretical model assumes that the pump laser intensity noise is white above 10 Hz.



CME4 Fig. 3. Subhertz heterodyne beatnote linewidth obtained when locking to the high-finesse interferometer.



CME5 Fig. 1. A polarization-switchable microchip laser. In the experiments discussed, the Nd:YAG crystal was 0.65 × 1.0 × 1.0 mm. The total distance between the pump mirror and the further of the two partially reflecting mirrors was ~3 mm.



CME5 Fig. 2. Voltage waveform (top trace) applied to the polarization-switchable microchip laser and the intensity of its output in one polarization (bottom trace).