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Passive q-switching of an erbium fibre laser using nonlinear reflection from a liquefying gallium mirror

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Abstract

Liquefying gallium shows a new type of huge, broadband reflective optical nonlinearity which we used for passive Q-switching of an erbium doped fibre laser. The Q-switching technique is compatible with lasers operating in both the visible and infra red.

It has recently been discovered that reflection from certain metallic surfaces can become highly nonlinear at temperatures close to the melting point [1,2]. To date the most dramatic effects have been seen with gallium for reflection at a gallium/glass interface held at temperatures just below the melting point of ~29.8 °C. This liquefying gallium nonlinearity (LGN), which we attribute to a second-order 'surface melting' phase transition at the proximity of the bulk solid:liquid melting point, is truly broadband extending from the visible out to the infra red. At 1550nm we have observed an intensity dependant increase in reflectivity of up to 30% for applied optical field strengths of ~ 10kW/cm^2 with response times of the order of 1μs [3].

Significantly faster response times (<100ns) have been observed at higher (100mW) input powers [3].

It is well known that the incorporation of a suitably fast nonlinear element within a laser system can lead to Q-switched operation. For Q-switching of a typical fibre laser response times of the order of 10ns to 1 μs are required and are readily obtained for practical system parameters using LGN. In this paper we describe a Q-switch fibre laser based on the use of an LGN mirror.

The laser layout is illustrated in Fig.1. The cavity is of a conventional ring design but incorporates a fiberised LGN mirror. The mirror is formed by inserting the cleaved end of a standard single mode fibre into a bead of gallium. Light is thus coupled back into the fibre with minimal loss after reflection at the gallium:glass interface. A circulator is used to separate the incident and reflected beams. The temperature of the gallium bead is accurately controlled at temperatures around the gallium melting point using an actively stabilized miniature Peltier heat pump. The Er^{3+}/Yb^{3+} doped fibre is pumped with up to 550mW of pump radiation at 1047nm from a Nd:YLF pumped laser.

At temperatures below the gallium melting point and at low pump powers typically below ~ 200 mW the laser operated in a cw mode. However, between certain well defined (but temperature dependent) pump power limits the laser entered a stable Q-switch regime (See Fig.2 (inset)). At still higher powers instabilities became apparent. The pulse duration was always in the range 1-2μs. The pulse repetition rates were between 20 and 100 kHz, the exact repetition rate being dependant on pump power and sample temperature. In Fig.2 we plot the pulse peak power as a function of pump power over the stable operating regimes for two gallium temperatures; the pulse peak power is seen to increase as we move away from the gallium melting point thereby compensating for the decreasing nonlinearity of the mirror. Note, that Q-switching was not observed with a molten gallium mirror, or any other conventional reflector inserted within the cavity further confirming LGN as the Q-switching mechanism.

These results represent a first demonstration of the application of LGN mirrors to laser systems illustrating their compatibility with waveguide devices. We anticipate that significant improvements in mirror design and laser performance will follow making use of the unique features of this manifestly nonlinear medium.

References

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Fig.1 Laser schematic.

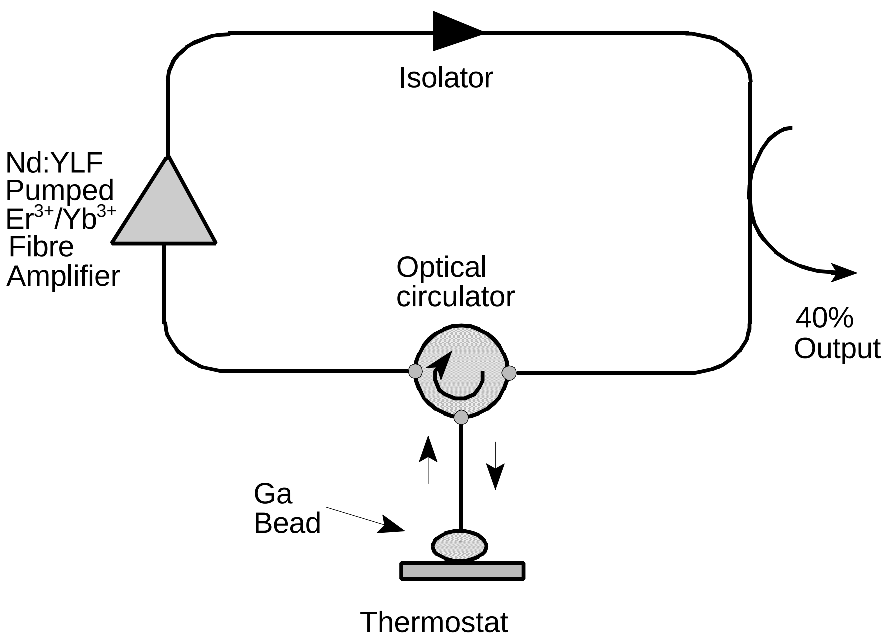

Fig.2 (Inset) Laser characteristic for a nominal gallium temperature of 17 °C showing: cw operating regime (A), stable Q-switching regime (B), unstable pulsing regime (C). (Main) Pulse peak power for two different gallium temperatures 5 and 17 °C. (Note that the quoted temperatures relate to the temperature of a metal plate in direct thermal contact with the gallium bead but not at the mirror interface which might in this instance be at a significantly different temperature due to local heating by the absorbed radiation.)

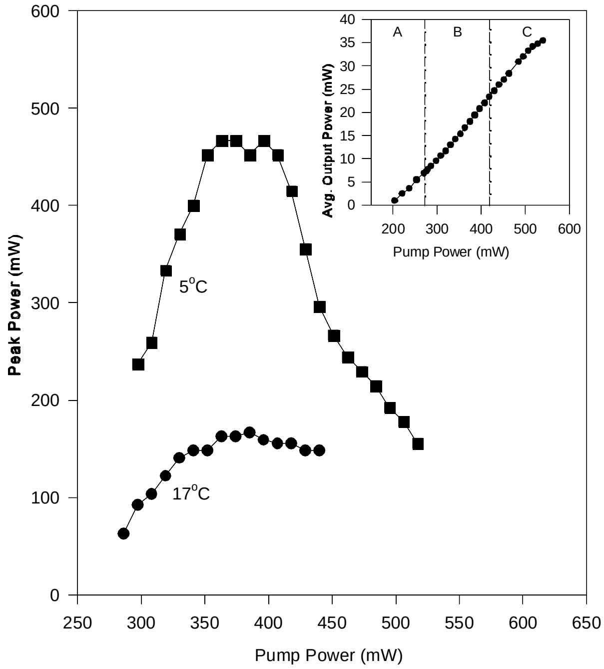

Fig.3 A typical Q-switch pulse train as measured at an operating temperature of 17 °C.