Broadband Optical Switching in Confined Gallium at Milliwatt Power Levels

S.Dhanjal[*], K.F.MacDonald[*], P.Petropoulos[†], D.J.Richardson[†] and N.I.Zheludev[*]

[*]Department of Physics and Astronomy,
University of Southampton,
Highfield, Southampton, Hampshire, SO17 1BJ, UK.
Tel: +44 1703 592699
email: kfm@phys.soton.ac.uk
n.i.zheludev@soton.ac.uk

[†]Optoelectronics Research Centre,
University of Southampton,
Highfield, Southampton, Hampshire, SO17 1BJ, UK.

Abstract

The optical nonlinearity of confined liquefying gallium offers a new technique for cross-wavelength all-optical switching at milliwatt power levels in a wavelength range spanning from at last 633 to 1550 nm.

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†Optoelectronics Research Centre,
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Summary

It has recently been discovered [1] that a liquefying gallium mirror created at a tip of single mode fibre shows a huge optical nonlinearity $\chi^{(3)} \sim 1$ esu, offering a new technique for controlling light with light. Here we report that the gallium interface nonlinearity is exceptionally broadband, and that we

have demonstrated all optical switching for certain wavelengths in the range 633 to 1550 nm.

In our experiments the radiation from two diode lasers operating at different wavelengths, for example λ_A= 1.55 µm (control) and λ_B = 1.3 µm (signal) was coupled into a gallium mirror created by immersing the cleaved end of a single mode fibre (mode area = 120 µm^2) in a small bead of gallium (see inset fig. 1). Modulation of the control beam's intensity induced a modulation of the gallium glass interface's reflectivity and thus caused a modulation of the signal beam's intensity. Hence the device operates as a cross-wavelength optical switch. Considerable modulation has also been seen with A and B beams at wavelengths of 670 and 633 nm respectively.

At temperatures well below the melting point the gate efficiency (signal modulation depth) increases with temperature (see fig. 1). There is no signal modulation at temperatures above the melting point. The switch-off time of the gate is about 100 ns at 25 degrees below the melting point (see fig. 2) and increases to a microsecond scale as the temperature approaches the melting point. The efficiency of the gate increases superlinearly as a function of the control beam peak power (see fig. 3).

We relate this huge broadband nonlinearity to a light induced structural phase transition in α-Ga. Optical excitation destabilises covalent bonding within the crystalline structure of α-Ga thus provoking a surface assisted transition to a more reflective, more metallic phase. Such excitations of bonding - anti-bonding transitions are associated with a broad absorption band spanning from 0.8 to 4 eV.

References

[1] P.J.Bennett, S.Dhanjal, V.I.Emelyanov, P.Petropoulos, D.J.Richardson and N.I.Zheludev, Appl. Phys. Lett., **73,** 1787 (1998).

Figure Captions

Fig. 1

The performance of the cross wavelength all-optical gate. The control pulses (Input A) had a wavelength λ_A = 1.55 µm, a duration of 100 ns and a repetition rate of 10 kHz. The signal radiation at Input B was continuous wave at a wavelength λ_B = 1.3 µm. The gate's output contrast ratio is presented as a function of the gallium bead temperature, T, (T_m = 30 °C). The inset shows a schematic of the fiberized gate.

Fig. 2

Gate switch-off time, τ, as a function of temperature, T. A typical gate response function with a 100 ns control pulse (dashed line) is presented in the inset for $T-T_m$ = -25 °C (T_m = 30°C).

Fig. 3

The signal contrast ratio as a function of the control beam peak power for various temperatures.

Fig. 1

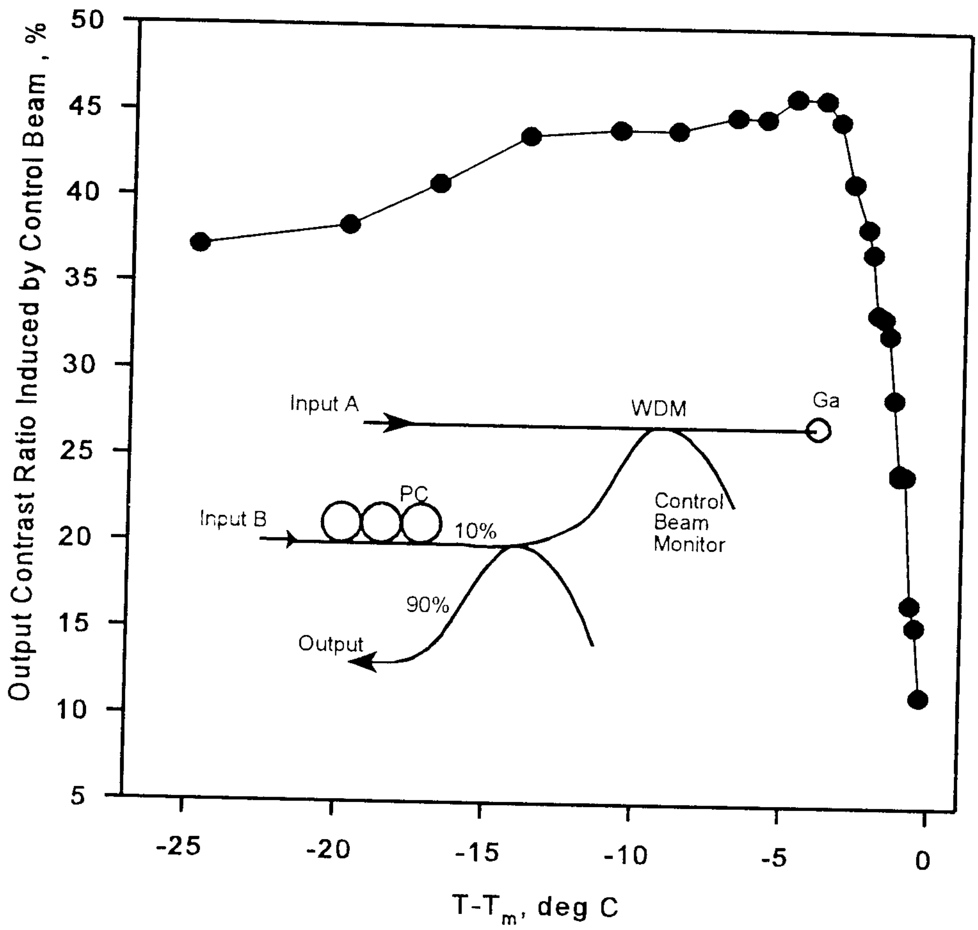

Output Contrast Ratio Induced by Control Beam , %
50
45
40
35
30
25
20
15
10
5
-25
-20
-15
-10
-5
0
T-Tm, deg C
Input A
WDM
Ga
Input B
PC
10%
Control
Beam
Monitor
90%
Output

Fig. 2

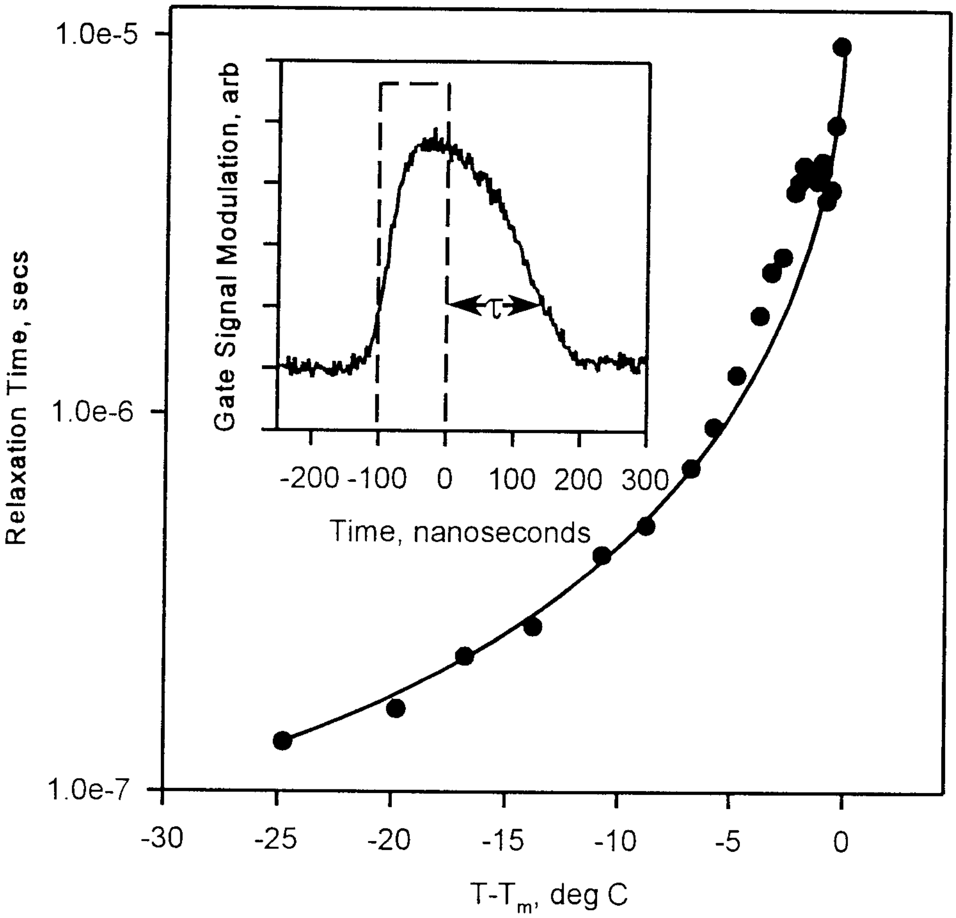
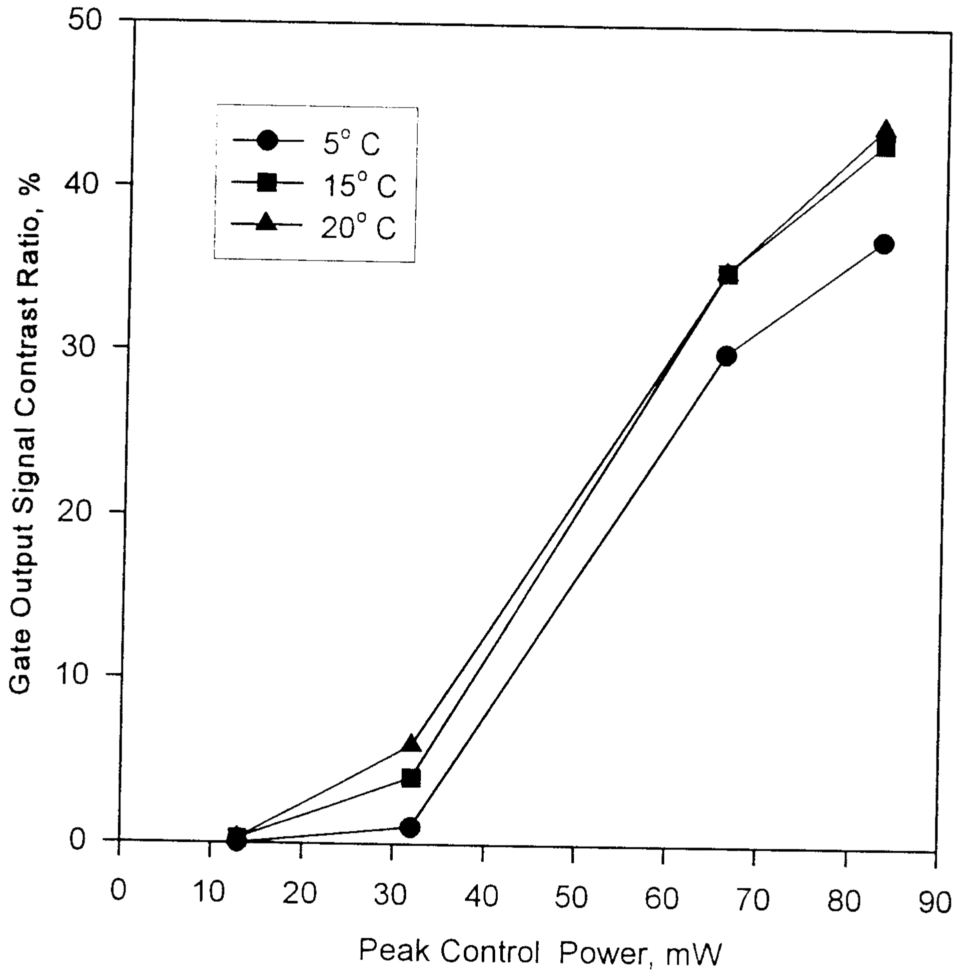

1.0e-5
1.0e-6
1.0e-7
Relaxation Time, secs
-30
-25
-20
-15
-10
-5
0
T-T$_m$, deg C
Gate Signal Modulation, arb
-200 -100 0 100 200 300
Time, nanoseconds
τ

Fig. 3



5° C
15° C
20° C
Gate Output Signal Contrast Ratio, %
0
10
20
30
40
50
0
10
20
30
40
50
60
70
80
90
Peak Control Power, mW