Observation of Slow Light in Ruby

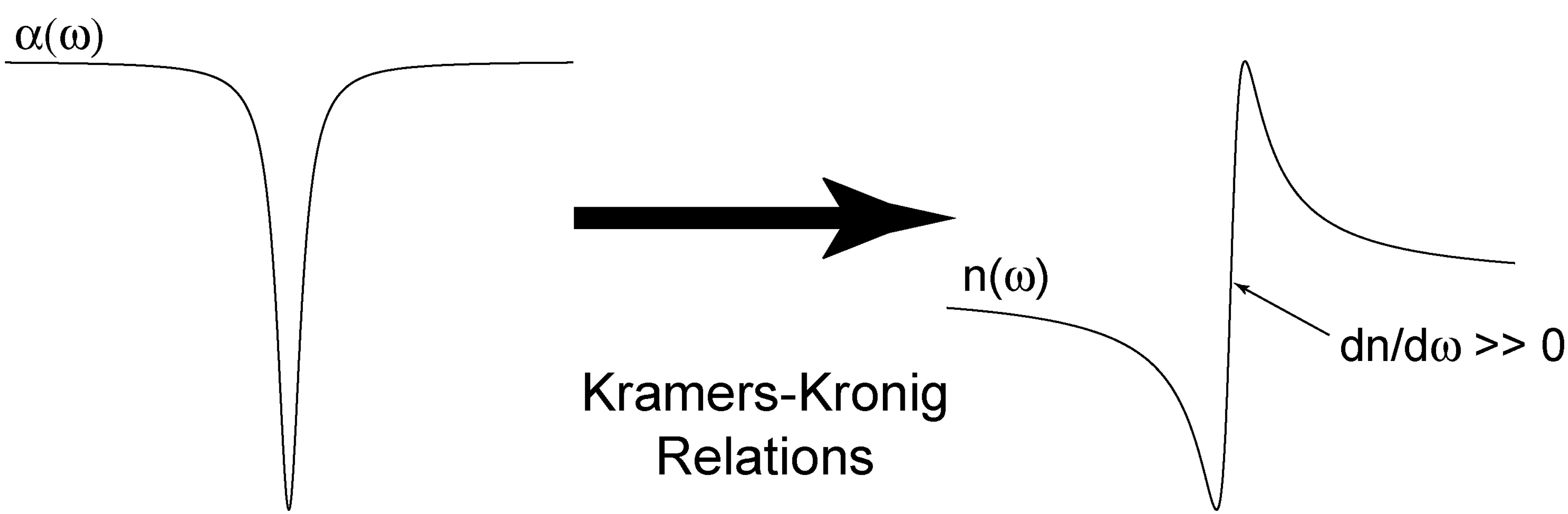
Matthew S. Bigelow, Nick N. Lepeshkin, and Robert W Boyd

The Institute of Optics, University of Rochester, Rochester, NY 14627

Monday, September 30, 2002

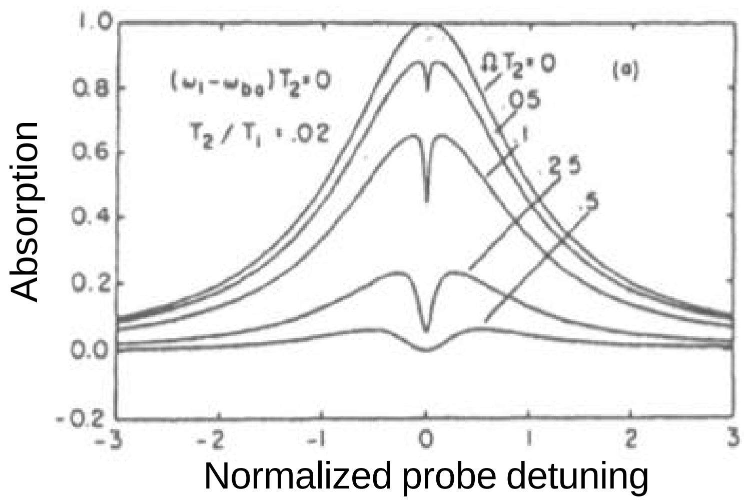
How to get slow light?

- Group index: $n_g = n_0 + w\dfrac{dn}{dw}$
- Want a very narrow dip in the absorption.



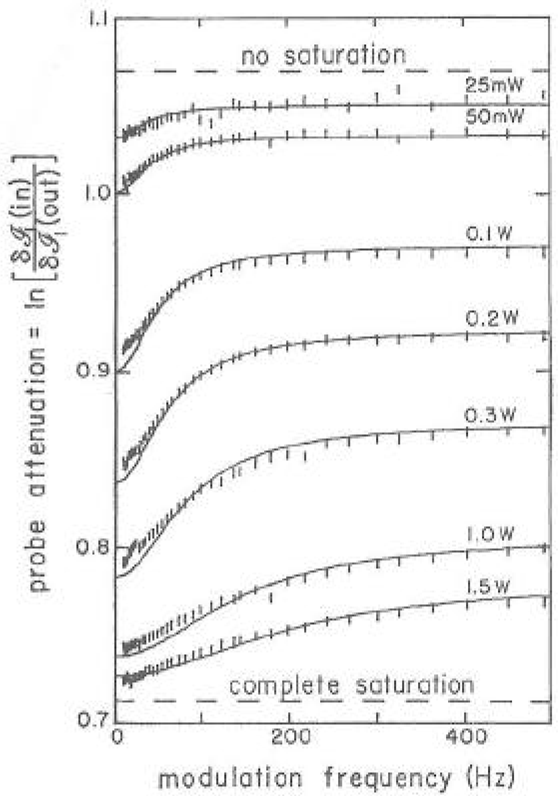
Holes in homogeneously broadened absorption lines

$T_2 << T_1$ (Collisional Broadening)



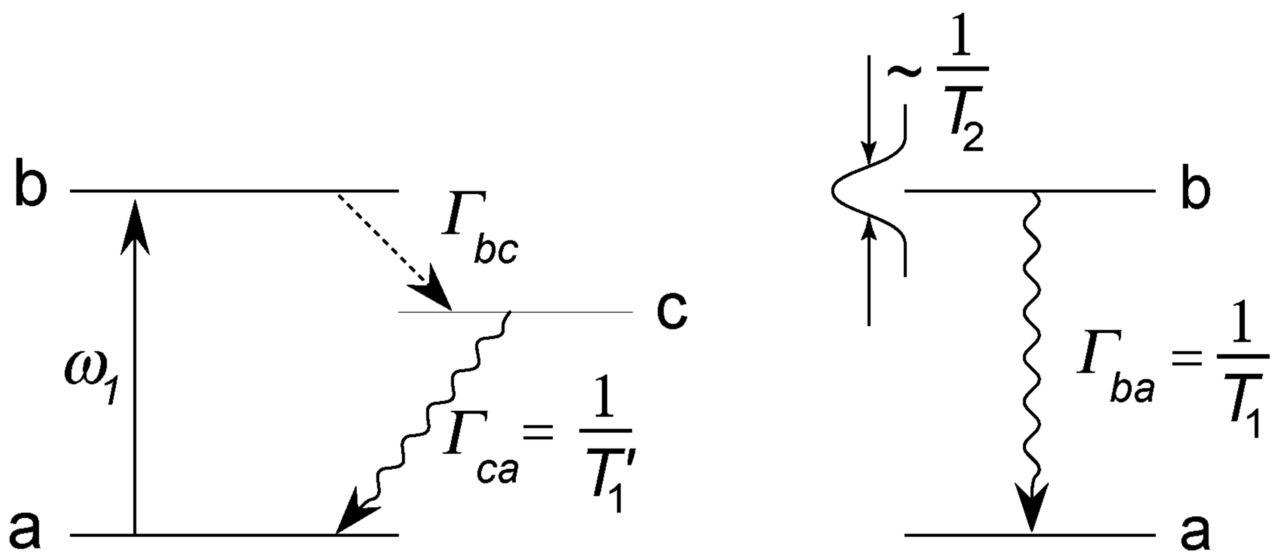
Boyd et al., Phys. Rev. A. **24**, 411 (1981)

37 Hz HWHM !



Hillman et al., Opt. Comm. **45**, 416 (1983)

Laser-ruby interaction



Coherent population oscillations

Population Inversion:

$$w \equiv r_{bb} - r_{aa},$$

$$w(t) \approx w^{(dc)} + w^{(-d)} e^{idt} + w^{(d)} e^{-idt}$$

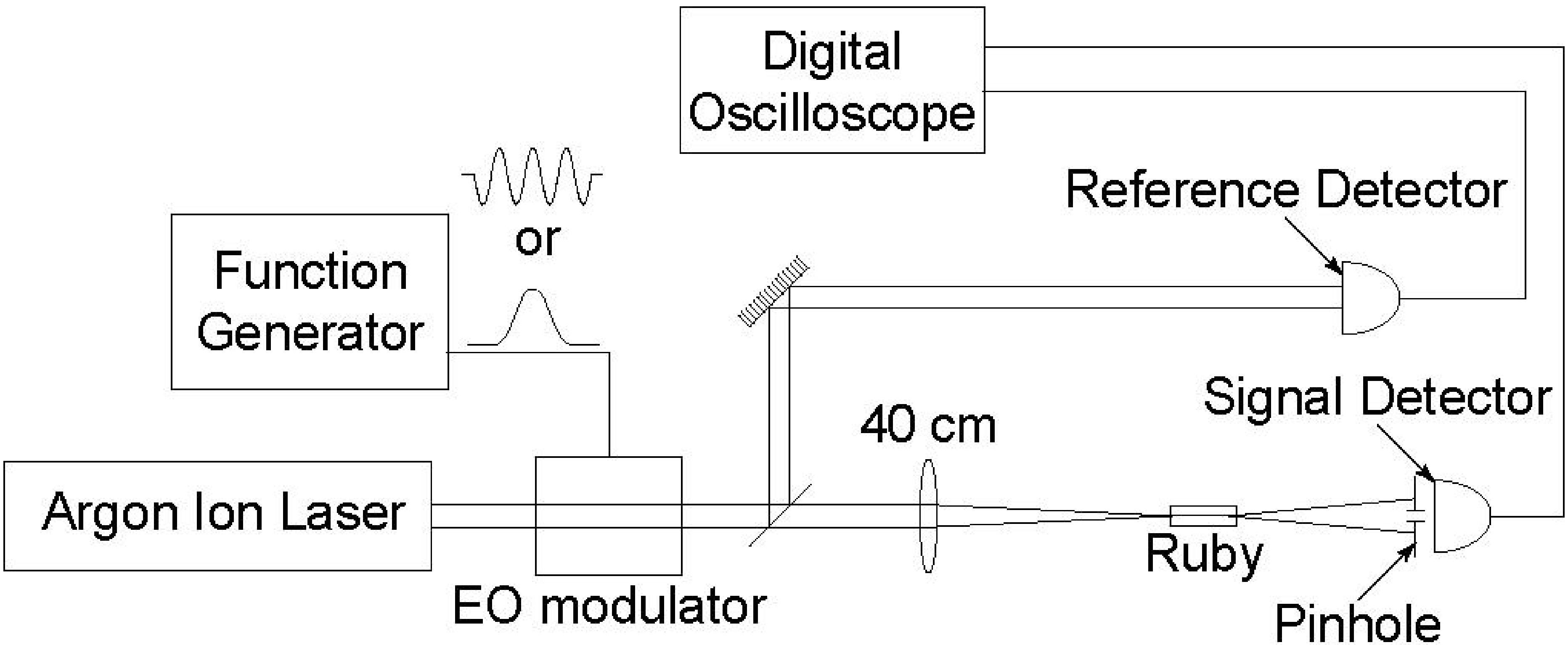
Probe-beam response:

$$r_{ba}(w+d) = \frac{m_{ba}}{\hbar} \frac{1}{w - w_{ba} + i/T_2} \left(E_3 w^{(0)} + E_1 w^{(d)} \right)$$

$$\Rightarrow \quad a(w+d) \propto \left(w^{(0)} - \frac{\Omega^2 T_2}{T_1} \frac{1}{d^2 + b^2} \right),$$

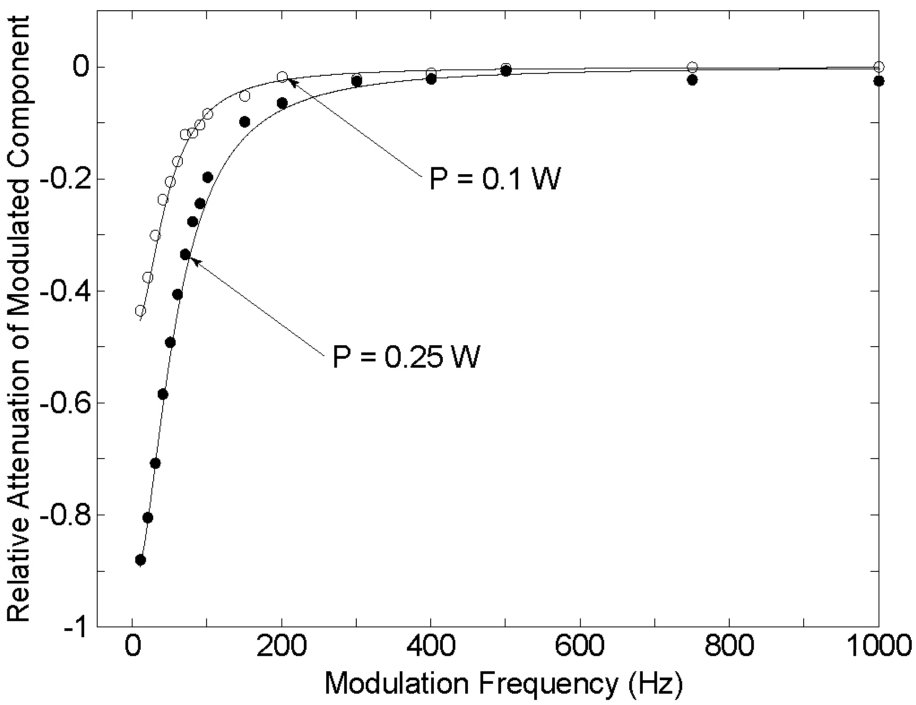
$$\text{where } b = \frac{1}{T_1}\left(1 + \Omega^2 T_1 T_2\right)$$

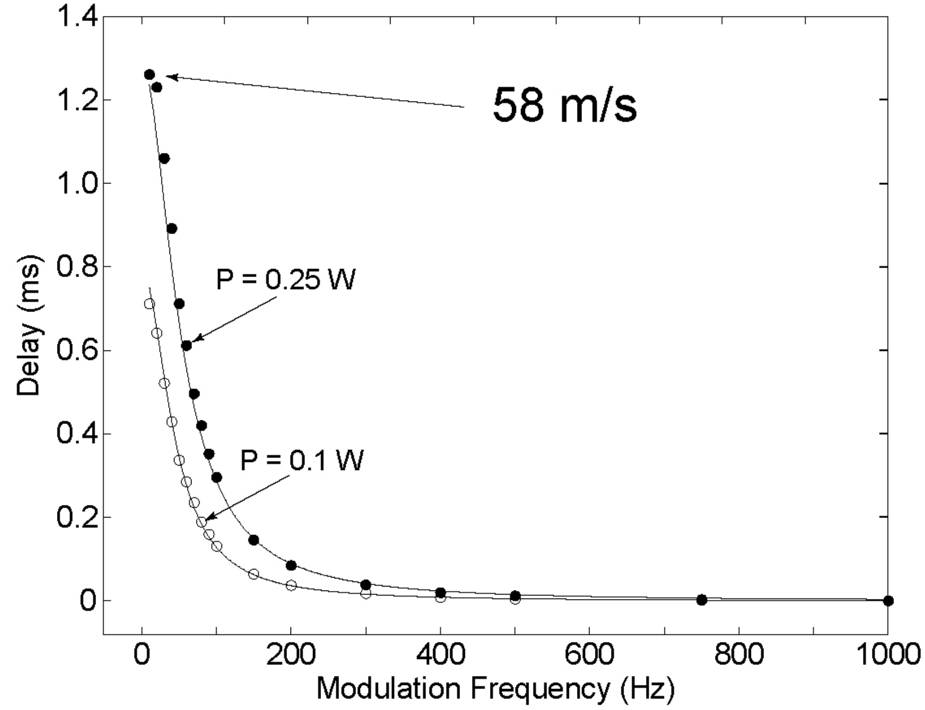
Experimental setup



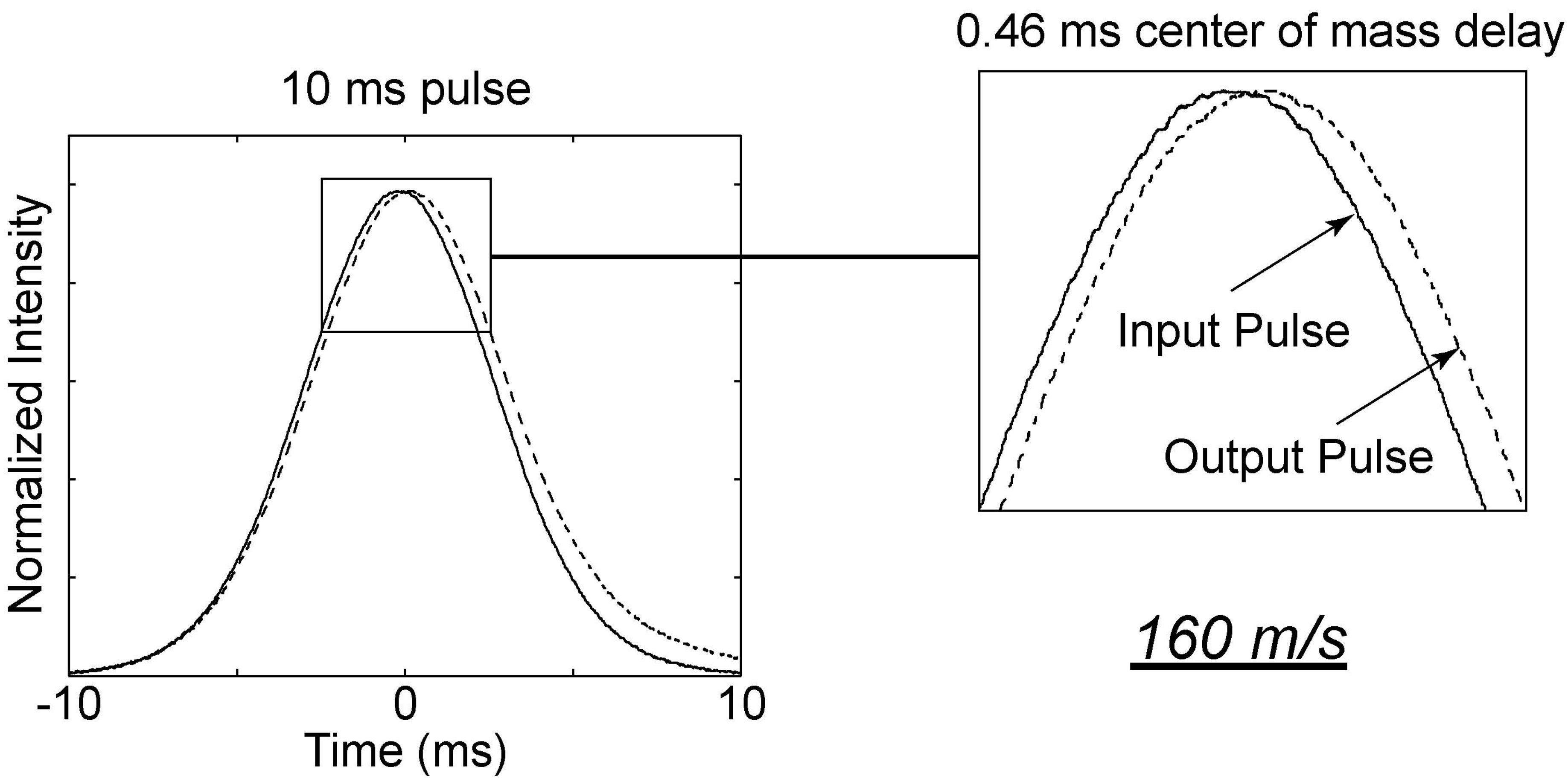
The Institute of Optics
Nonlinear Optics
University of Rochester

Modulation delay





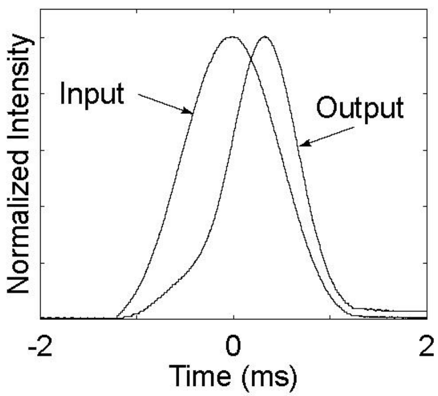
Whole-beam pulse delay



160 m/s

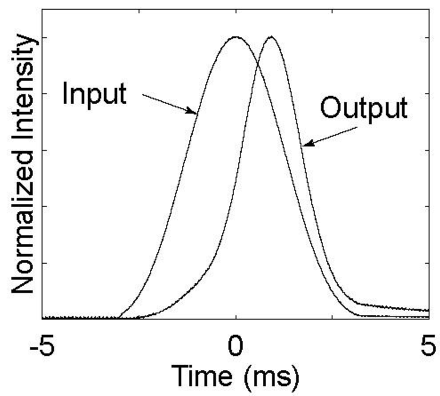
Off-axis pulse delay

2 ms pulse



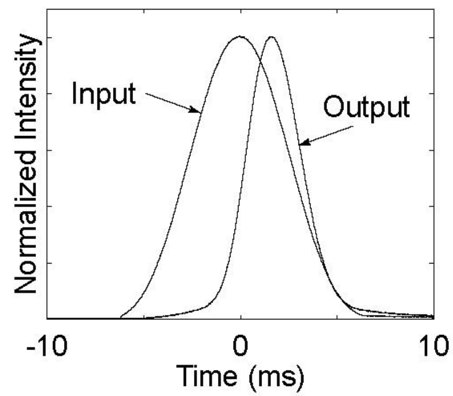
$v_g = 240 \text{ m/s}$

5 ms pulse



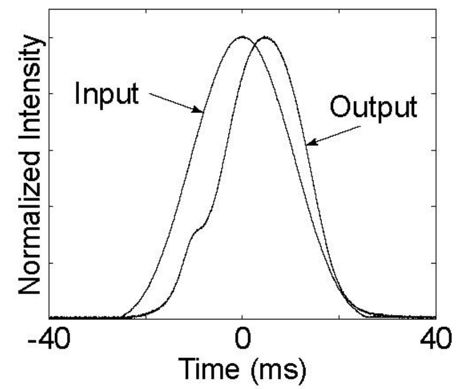
$v_g = 82 \text{ m/s}$

10 ms pulse



$v_g = 40 \text{ m/s}$

40 ms pulse



$v_g = 19.5 \text{ m/s}$

Advantages

- In a solid (ruby).
- At room temperature.
- Single laser beam (self-delayed).
- Laser need not be frequency stabilized.
- Delay can be controlled by changing the pulse width, changing the input intensity, or by looking at a different part of the beam.

The Institute of Optics
Nonlinear Optics
University of Rochester

Conclusions/Future Work

- We have observed group velocities in ruby as low as 19.5 m/s.
- Since it is so easy, this method has more potential in applications.
- Investigate enhanced nonlinear optical interactions (forward SBS).