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H.W.H. Lee, R.S. Hughes, Jr.,
J.E. Davis, C.F. McConaghy, A.V. Hamza, and M. Balooch

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Feasibility of Fullerene Thin Films for High-Speed All-Optical Switching

Howard W. H. Lee, Robert S. Hughes, Jr., Jeffrey E. Davis, Charles F. McConaghy,
Alex V. Hamza, and Mehdi Balooch

ABSTRACT

We measured the optical nonlinearity of fullerene thin films (C_{60} , C_{70}) from 710-850 nm and determined the figure of merit for all-optical switching. We also demonstrated, to our knowledge, the first fullerene-based all-optical switch.

A major deterrent to the practical implementation of high-speed optical switching is the availability of materials with appropriate properties such as sufficiently large optical nonlinearities and that are easily incorporated into devices. We have been studying fullerene thin films, specifically C_{60} and C_{70} , for this purpose. To assess the optical nonlinearity, we developed a novel and simple technique to measure the nonlinearity. This technique, Antiresonant Ring Interferometric Nonlinear Spectroscopy (ARINS) [1], affords accurate and simultaneous determination of the real and imaginary parts of the optical nonlinearity at low optical powers. This is essential to preclude other processes from interfering with the measurement as observed in many previous attempts. ARINS is further able to eliminate thermal processes from affecting the measurements.

We show that the advantages of fullerenes (C_{60} and C_{70}) include large Kerr indices (n_2), relatively small two-photon absorption coefficients (β), fast optical response times, and ease of device fabrication. Our nonlinear measurements cover the range from 710-850 nm. We find large n_2 's ranging from 7.0×10^{-11} to $2.0 \times 10^{-9} \text{ cm}^2/\text{W}$. We also find that the response times of the resonant and nonresonant nonlinearity range from picoseconds to subpicoseconds. These

parameters give competitive figures of merit (FOM) based on $FOM=2n_2/(\beta\lambda)$. Using our measured dispersion of the FOM, we have identified spectral regions where it would be desirable to operate fullerene-based all-optical switches.

We have also demonstrated, to our knowledge, the first fullerene-based all-optical switch. The switch consists of a fullerene thin film (160 nm) in an antiresonant ring (ARR) and operates in a fashion similar to a nonlinear optical loop mirror (NOLM). We used the same setup as in the ARINS nonlinear measurements. The device operated at 82 MHz and required a few picojoules to switch. We emphasize that this is a preliminary result and the operating parameters such as the switching speed and energy have not been optimized. In addition, we have not fully assessed the thermal heating contribution, if any, to the switching operation. However, if the femtosecond dynamics of the measured nonlinear response can be directly translated into switching speed, then THz switching rates may be possible.

All-optical switching with NOLM's have received considerable attention recently because of the favorable FOM of optical fibers. However, the small n_2 in fibers necessitates extremely long lengths of fiber (100's of meters to a kilometer) to accumulate the desired phase shift. Size and latency become important limiting issues. We therefore considered an integrated optics approach with fullerenes as one possible nonlinear optical material. With this in mind, we have demonstrated the patterning of fullerene thin films into channels for guided wave integrated optics. This is achieved by vapor deposition onto etched polymer photoresist, followed by solvent liftoff of the resist. The processing of fullerene guided wave structures proved straightforward and will be discussed. This integrated optics approach will allow considerably smaller devices and minimize or effectively eliminate the latency problem.

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References

1. H. W. H. Lee and R. S. Hughes, Jr., *Optics Letter*, submitted, 1993; H. W. H. Lee and R. S. Hughes, Jr., *Conference on Lasers and Electro-Optics*, May 10-15, 1992, Anaheim, CA., paper CTuK2.