Birefringent Bistability in Ferroelectric Waveguides

BY FEILING WANG AND GENE H. HAERTLING, CLEMSON UNIVERSITY, CLEMSON, S.C.

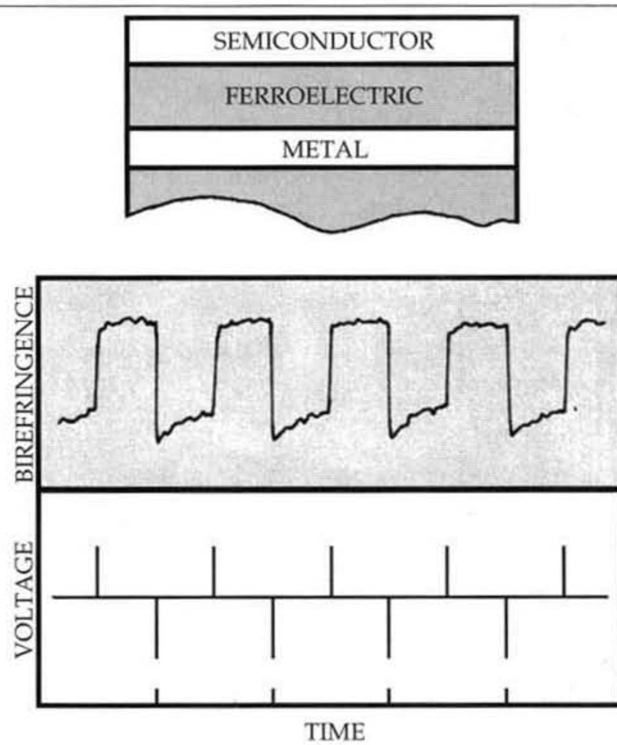
Some ferroelectric materials are known to possess outstanding transverse electro-optic properties, namely, the electric-field-controlled birefringence. Great efforts have been made to study ferroelectric thin films to determine their use in integrated optoelectronic devices where light may be modulated or switched in ferroelectric waveguides by electric signals.[1] It is well known that the remanant polarization in a ferroelectric material can be switched between two opposite directions with an external electric field; however, much to everyone's dissatisfaction, the polarization reversal causes no consequence for optical waves propagating in normal ferroelectric materials because the birefringence of a ferroelectric material depends quadratically on polarization. Nonvolatile light modulation and binary switching by means of polarization reversal in normal ferroelectric materials are thus prohibited.

The symmetry in the optical properties under polarization reversal may be broken if one of the polarization directions is made more favorable than the other because of certain electrode combinations. The phenomenon of a birefringent bistability associated with the polarization reversal in ferroelectric lead lanthanum zirconate titanate (PLZT) thin films has been recently observed by the research group at Clemson University.[2]

Birefringent bistability was detected from a thin film metal/ferroelectric/semiconductor (MFS) structure shown in the figure at the right. The ferroelectric PLZT thin film was sandwiched between a platinum and a semiconducting indium-tin oxide (ITO) layer. When an electric signal was applied to the platinum and the ITO layers, the sandwiched PLZT thin film became birefringent with its c axis parallel to the normal of the film surface. It was found that bipolar electric pulses switched the PLZT film between two optically distinguishable states that were different in birefringence by approximately 0.9×10^{-3}. The nonvolatile nature of the birefringent switching in the MFS device is clearly depicted in the figure. After a positive pulse, the PLZT film remains in a low birefringent state until the following negative pulse switches the material to a high birefringent state.

Another type of birefringent bistability that involves the field-induced antiferroelectric-ferroelectric phase transition has also been experimentally observed in lead zirconate thin films.[3]

The birefringent bistability exhibited in the MFS structure and the lead zirconate thin films may allow ferroelectric waveguides to perform some key functions in such electro-optic modules as programmable spatial light modulators and nonvolatile electro-optic memories. These devices play important roles in optical signal processing and optical computing systems.



Birefringent bistable switching in the MFS device using bipolar electric pulses. The electric pulses are 0.1 ms in pulse width and 15 V in peak power. The birefringent difference between the two states is 0.9×10^{-3}. The horizontal scale is 10 seconds per division.

References

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