Optically Rewritable Solitonic Waveguides in Lithium Niobate Films for Reconfigurable Photonic Devices

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Abstract. We experiment a fast, localized, and fully optical erasure procedure for photorefractive solitonic waveguides written in lithium niobate on insulator (LNOI) thin films. This method enables real-time reconfiguration of self-written optical circuits by exploiting photovoltaic field-driven charge redistribution.

1 Introduction

Photorefractive screening solitons, known for their low-power generation thresholds, offer a versatile platform for integrated optics [1]. Advances in using pyroelectric fields, induced via thermal gradients, have simplified the fabrication of these waveguides by removing the need for externally applied voltages [2]. These structures exploit optically excited charge distributions to form buried waveguides capable of guiding light with minimal losses. Depending on the dielectric relaxation properties of the host material, the refractive index changes may persist over varying timescales—from transient to quasi-permanent. Lithium niobate bulk crystals, for instance, support long-lasting solitons, while other materials such as strontium barium niobate or indium phosphate support transient effects. Of particular interest are semi-permanent structures, as they enable both reliable guidance and controlled erasure, which is crucial for adaptive photonic systems. In general, erasing written structures means eliminating the distribution of the photogenerated charges, for example by re-exciting them optically and then applying an electric field to redistribute them throughout the whole material [3]. In this work we present an innovative in-situ Optical Erasure of X-Junction channels inside LNOI.

2 Experiment and Results

In this work, we employ 8 μm-thick undoped LNOI films and generate solitonic X-junctions using two intersecting incoherent beams at 532 nm under a pyroelectric bias induced by a thermal gradient (ΔT) [4]. Once the structures are written, the thermal field is eliminated, and high-power re-illumination (80× the writing intensity) is used to erase the waveguides. This reactivation mobilizes trapped charges via strong local photovoltaic fields, effectively eliminating the index contrast. The protocol allows rapid, localized, and repeatable erasure without removing the sample from the optical setup.

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We document the real-time erasure process using imaging as reported in figure 1A and simulations (shown in figure 1B).

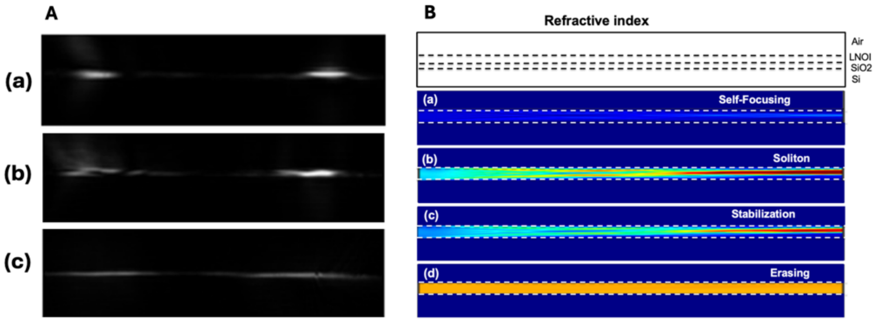

Fig. 1. A: Erasure sequence of an unbalanced X-junction. The channel with higher refractive index contrast (left side) requires more time to be fully erased compared to the lower-contrast channel (right side). B: refractive index evolution during the phases of diffraction for time a) t=2.5s, self-confinement b) t=100 s, stabilization c) t=120 s and erasing d) t=280 s.

Initially, confined beams begin to diffract as charge redistribution progresses, eventually restoring the original unmodulated refractive profile. The efficiency of this process is markedly improved in thin films, likely due to reduced densities of deep-level traps and enhanced surface charge mobility. Asymmetric (unbalanced) X-junctions demonstrate differential erasure dynamics between channels, governed by local intensity variations and charge distributions. Despite these asymmetries, full erasure is achieved in all cases. Repetition across multiple write–erase cycles shows no loss in photorefractive efficiency.

3 Conclusions

This work introduces a robust, fast, and fully optical mechanism for rewriting integrated photonic circuits based on solitonic waveguides. Beyond its practical implications for reconfigurable optics, the protocol enables the physical implementation of "forgetting" functions in optically-driven neural networks. Writing corresponds to learning, while erasure provides the physical substrate for adaptation and reconfiguration [6]. Future work will investigate multiplexed erasure, integration with plasmonic components, and the development of adaptive neuromorphic photonic systems.

References

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