Method to fabricate a waveguide in a substrate using a femtosecond laser

KEYWORDS

- ❑ INTEGRATED PHOTONICS
- ❑ POLARIZATION OF LIGHT
- ❑ DELAY FOILS
- ❑ WAVE GUIDES
- ❑ QUANTUM TECHNOLOGIES

AREA

- ❑ ELETTRICAL ELECTRONIC & ICT ENGINEERING

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Patent for invention.

Co-Ownership
Sapienza Università di Roma 10%, CNR 90%.

Inventors
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Industrial & Commercial Reference
Research activity that is part of the area of photonics and quantum technologies.

Time to Market
Technology has been tested in the lab with an experiment demonstrating the operativity of the scheme, reported in Nature Communications 5, 4249 (2014), TRL Level 4..

LICENSED

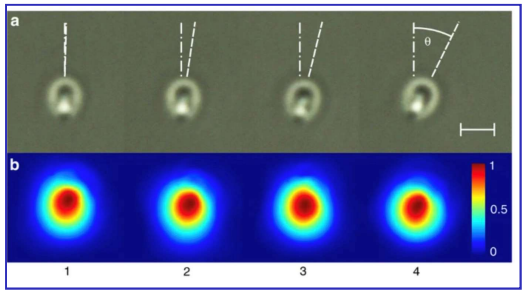
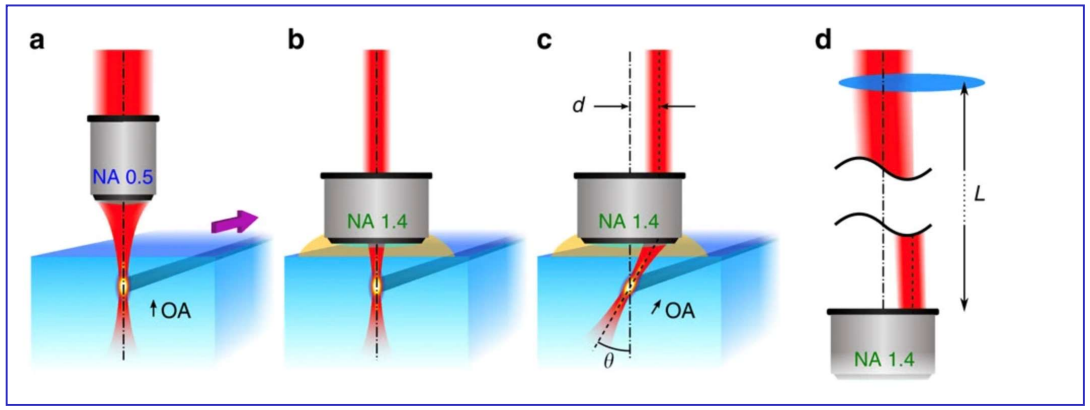


Fig. 1 (a) End-view microscope images of waveguides (labelled 1–4) showing a progressive rotation of the cross-section as the offset d of the writing beam is increased. Scale bar, 5 μm. (b) Near-field profiles of the waveguide modes at different rotation angles

Fig. 2 Conceptual scheme of the method enabling the direct writing of optical waveguides acting as integrated waveplates with tilted axis.



Abstract
Method for manufacturing with femtosecond laser technology, optical waveguides with an inclined birefringence axis, usable in all respects as integrated birefringent waveplates. The simplicity of the proposed method makes it particularly interesting, especially when compared with the complexity required to manufacture equivalent devices with lithographic techniques.

Pubblicazioni

❖ G. Corrielli, A. Crespi, R. Geremia, R. Ramponi, L. Sansoni, A. Santinelli, P. Mataloni, F. Sciarrino, R. Osellame, Rotated waveplates in integrated waveguide optics, Nature Communications 5, 4249 (2014).

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Technical Description

A method for realizing an optical waveguide in a substrate by means of a femtosecond laser system, the waveguide including a birefringence axis tilted by a predetermined angle for at least a segment, is disclosed. The method includes preparing a substrate including a free surface, focusing a femtosecond laser beam into the substrate, to induce a refractive index modification of a volume of such substrate around the focal region.

The method further includes varying a propagation direction of the femtosecond laser beam to reach a propagation direction describing a predetermined non-vanishing angle with respect to the normal to the free surface of the substrate and translating the focal region with respect to the substrate, in order to generate the waveguide segment.

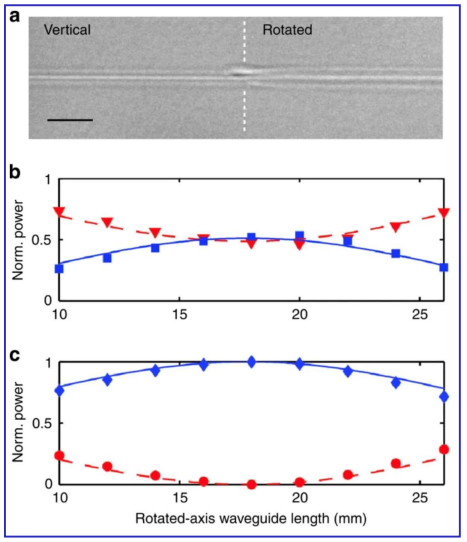
Technologies & Advantages

Controlling and manipulating the polarization state of a light beam is crucial in applications ranging from optical sensing to optical communications, both in the classical and quantum regime, and ultimately whenever interference phenomena are to be exploited. In addition, many of these applications' present severe requirements of phase stability and greatly benefit from a monolithic integrated-optics approach. However, integrated devices that allow arbitrary transformations of the polarization state are very difficult to produce with conventional lithographic technologies. This patent describes a technique to fabricate waveguide-based optical waveplates, with arbitrarily rotated birefringence axis, by femtosecond laser pulses. This approach opens perspectives for integrated manipulation of polarization-encoded information with relevant applications ranging from integrated polarimetric sensing to quantum key distribution.

Fig. 3 (a) Top-view microscope image of a junction between two waveguide sections having different tilt angles. Scale bar, 10 μm. Several waveplates with a designed optical axis tilt of θ=22.5° with different lengths have been characterized; for horizontally polarized input light, the measured normalized power transferred into (b) the horizontal (red triangles)/vertical (blue squares) polarization states and (c) diagonal (blue diamonds)/antidiagonal (red circles) polarization states is reported.

Applications

The present invention allows to fabricate waveguide segments acting as integrated waveplates, with precise control of the tilt angle. This approach is much simpler and cost-effective than other lithography-based techniques to realize integrated polarization converters. It can find application both in classical optics and for quantum technologies: in the context of quantum sensing, that is, the field which investigates the adoption of quantum resources to enhance the sensitivity in the measurement of relevant physical quantities, quantum cryptography and photonics quantum information processing.



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