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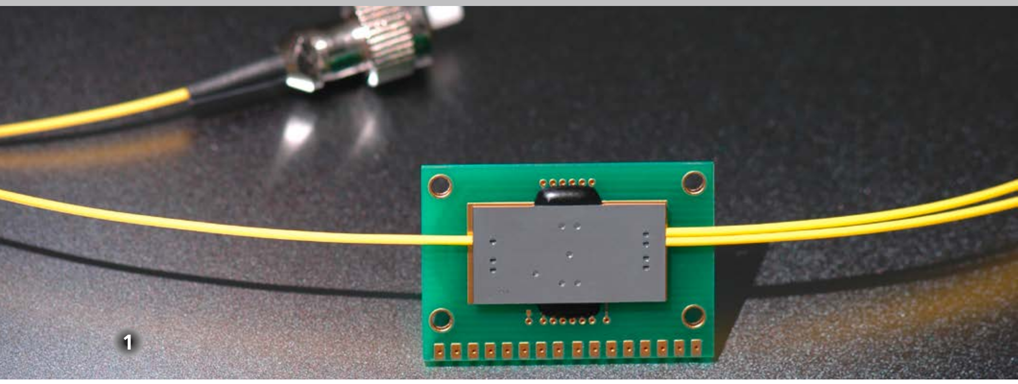
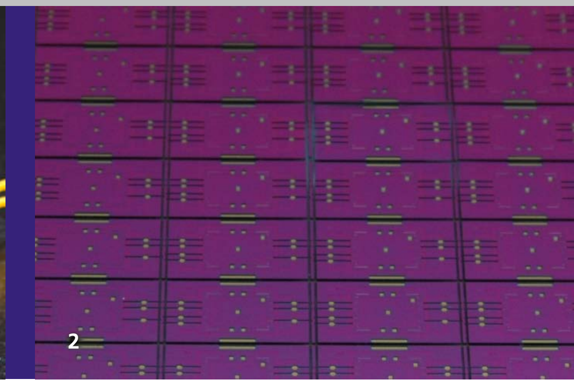




1 *Fiber-optic coupled 1 × 2 liquid crystal switch.*
2 *Wafer with processed top parts of the liquid crystal switch chips.*

ELECTRO-OPTICAL LIQUID CRYSTAL WAVEGUIDE SWITCH

Fraunhofer Institute for Photonic Microsystems IPMS

Maria-Reiche-Str. 2
01109 Dresden

Contact

Dr. Michael Scholles
Phone +49 351 8823-201
michael.scholles@ipms.fraunhofer.de

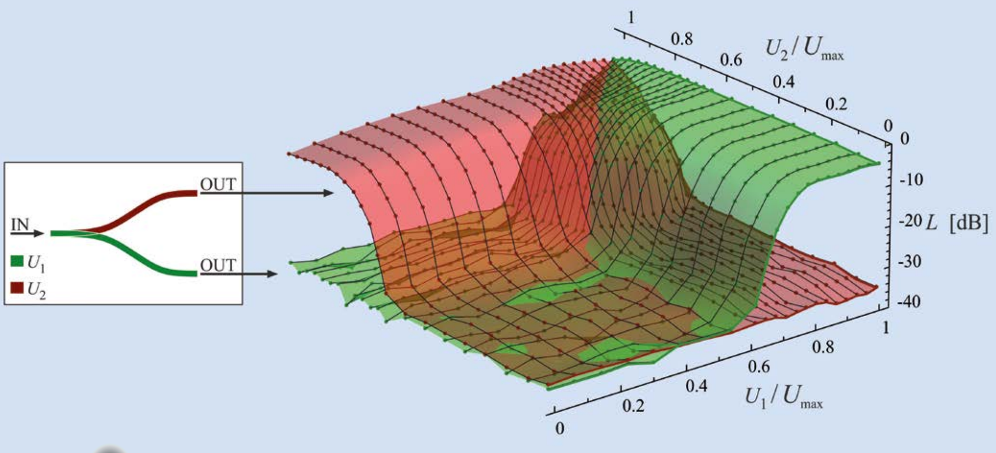
Dr. Florența Costache
Phone +49 351 8823-259
florenta.costache@ipms.fraunhofer.de

www.ipms.fraunhofer.de

In optical telecommunication networks and fiber-optic sensor networks, the dynamic optical path control is realized through various control functions including optical switching. The ever-growing demands on switching performance as well as scalability and integration with other network devices pose continuously technological challenges on existing technologies. The Fraunhofer IPMS developed innovative optical switches based on electro-optically induced waveguides (EOIW) in liquid crystals, which excel both in performance as well as capabilities offered by the underlying technology.

Electro-optically induced waveguides in liquid crystals

An optical waveguide, i.e. EOIW, can be induced in a layer made from a material of large electro-optical (EO) constant by applying an electrical field across it, within regions delimited by stripe-shaped electrodes. Hence, a refractive index change is produced in this region, which acts as a waveguide core. Light coupled in this region is guided and can be collected at the waveguide output. The Fraunhofer IPMS uses nematic liquid crystals in their isotropic phase as core materials for its EOIW based devices. The particularity of these liquid crystals is that they exhibit, when heated just above their nematic-isotropic phase transition, a remarkably large EO Kerr effect (with EO Kerr constants of about 10^{-10} m/V²). Accordingly, an electric field of a few V/µm applied on liquid crystals in this particular phase can give rise to local anisotropies in the order of $\Delta n < 10^{-3}$. This Δn is large enough to permit the formation of a waveguide in the EOIW based device. In addition, these liquid crystals in isotropic phase show excellent transparency over a broad spectral range as well as response times shorter than a microsecond.



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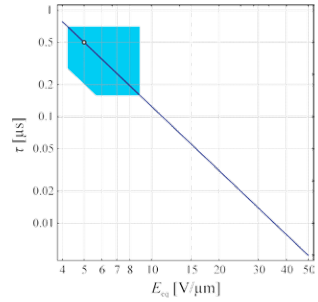

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These are properties of utmost importance for the device performance.

Design – Fabrication – Operation

Switches based on the EOIW concept are manufactured at the Fraunhofer IPMS by means of planar silicon technology. The Fraunhofer IPMS' optical switch chip (fig. 1) is made from two processed silicon wafers – forming the base and the top parts of the chip – each including structured electrode stripes and low refractive index claddings. Fig. 2 shows an image of the wafer with structured chips (i.e. the top wafer). The wafers are bonded together enclosing in between a layer made of liquid crystal. For device operation, an electrical field is applied between selected electrodes from both parts of the chip and across the liquid crystal layer. Light waves are guided on the paths, in this way "activated", at an optical loss of about 0.5 dB/cm.
A 1 × 2 fiber-optic switch chip is available to date. Figs. 3 and 4 show the most important measured characteristics of the chip: insertion loss at the chip's two output channels and switching time. For the purpose of the demonstration of the EOIW underlying concept, fig. 5 presents a chip with the top part made of glass coated with ITO, which acts as the counter electrode. When visible light is coupled into the chip, the activated waveguide can be directly visualized.

Advantages

Optical switches with no moving parts, such as the Fraunhofer IPMS' liquid crystal based devices, warrant high operation stability and reliability. The switch makes use of isotropic liquid crystals, which provide the device short switching times and excellent transparency over a broad spectral range. These devices are fabricated by means of high precision, planar silicon technology and therefore are suitable for high volume, cost-effective manufacturing. An additional benefit is that these switches can be easily integrated with other devices. Their design can be adjusted according to the desired application.

Technology options

The technology based on such "active" optical waveguides permits, just by structuring of suitable electrode paths on the chip, the fabrication of optical switches with multiple inputs and outputs for either single-mode or multi-mode operation. The Fraunhofer IPMS can further extend the functionality of the chip to optical interconnection and attenuation as well as power splitting and modulation in a straightforward way with appropriate design and technology adjustments.

Key features

- No moving parts
- Stability of switching
- Reliability
- Continuously voltage-adjustable output characteristics
- Precision silicon micro-technology
- Wafer level scale manufacturing
- Scalability and integrability with other devices

Applications

- Fast fiber-optic sensor networks
- Optical telecommunication networks
- Laser technology
- Signal monitoring
- Fiber-to-fiber interconnection
- Signal attenuation

3 *Measured insertion loss vs. applied voltage for the two output channels.*

4 *Switching time vs. the applied electrical field on the waveguide. The blue marked area designates the parameter space for currently available devices.*

5 *Input to output 1 switching by means of induced waveguides in the liquid crystal chip.*

Technical specifications

Parameter	Unit	Value
Insertion loss* (at 1550 nm)	dB	< 3
Attenuation range	dB	0 - 30
Wavelength range	nm	400 - 1600
Optimized for wavelength	nm	1550
Switching time	ns	< 100

* for TM polarization

For more information scan here