MEMS modulated photonic integrated circuits

Motivation

Photonic integrated circuits

In contrast to traditional electronic circuits, photons are utilized for signal distribution and processing inside photonic integrated circuits (PICs). The building blocks of PICs are optical waveguides, structured on various material platforms such as Si or SOI, which can be switched by modulating the refractive index thermally, electro-optically, acousto-optically and stress-optically. The state-of-the art in silicon-based PICs is to combine the advantages of high bandwidth and fast processing capabilities, reducing transmission losses as well as lowering thermal heating and energy consumption. Their compact chip design and CMOS-compatibility build the foundation for large volume, cost-efficient fabrication of PICs. Due to intense research and the introduction of new materials within the last decade, PICs have gained significant relevance across a broad field of applications, ranging from quantum computing and precision sensing to high-speed data processors, laser systems, and biomedical products. For the realization of multifunctional PICs with actively switchable components, efficient modulation of the waveguides´ optical properties is essential.

Piezoelectric modulation

To tune the waveguide´s optical properties, piezoelectric modulators are monolithically integrated on wafer-level in close vicinity to the waveguide. When an electric voltage is applied to the piezoelectric stack, the generated electric field leads to an expansion or compression of the piezoelectric layer through the inverse piezoelectric effect. This mechanical deformation induces strain and stress in the waveguide and changes its effective refractive index via the stress-optic effect. The main advantages of the piezoelectric modulation of optical waveguides are high modulation frequencies, comparably low power consumption as well as compatibility with Si, SiN and SiON fabrication. An alternative modulation method can be realized by the combination of a piezoelectric layer and interdigital transducers (cf. Fig.2) so that the waveguides are modulated acousto-optically by the generation of surface acoustic waves (SAW).

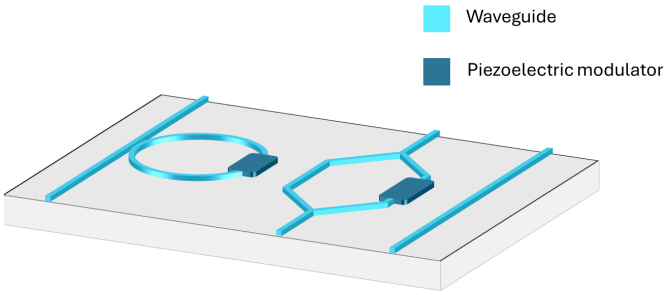


Fig. 1. Schematics of typical components for PICs, including ring resonators (upper left) and Mach-Zehnder interferometers (middle).

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More information

Technological capabilities at ISIT

The Fraunhofer Institute for Silicon Technology is specialized in the development and manufacturing of a wide variety of acoustic and optical microelectromechanical systems. Its state-of-the-art technological equipment based on 200 mm silicon wafer technology enables the implementation of technically sophisticated, innovative approaches as well as the subsequent prototype production on an industrial scale. A team of over 180 employees assists the ISIT´s customers from design and system simulation to prototype production, sampling and series preparation. ISIT´s expertise in the deposition and processing of silicon oxides and nitrides as well as its in-depth experience in the implementation of lead-free piezoelectric materials for MEMS actuators on industrial scale, makes it a powerful partner in the field of photonic integrated circuits. The institute is equipped and qualified to characterize the electromechanical properties of the piezoelectric and MEMS-modulator on wafer- and chiplevel.

Piezoelectric materials at ISIT

Piezoelectrically driven MEMS have been designed and manufactured at ISIT for more than 15 years. Substantial effort has been spent to develop stable and reproducible fabrication processes of high-performant Aluminum Scandium Nitride (AlScN) piezoelectric thin films. AlScN thin films possess high electromechanical coupling, reliable long-term stability even at elevated temperatures as well as the possibility of bipolar and bias-free driving. Its piezoelectric coefficient is significantly enhanced by Scandium doping and can be even further increased by the ISIT-patented technology of multilayer stacking. The (post)-CMOS-compatibility allows the integration of AlScN-based modulators on Si, AlN or SiN-waveguide platforms.

Our portfolio:

Design & PIC conception

- Finite element simulations of piezoelectric as well as SAW modulators and integrated waveguide structures
- MEMS design (optic, acoustic, magnetic)

Manufacturing (CMOS-compatible on 8 inch wafers)

- Stress-optimized deposition (LPCVD and PECVD) of various PIC-relevant materials, such as SiN, SiO,SiON on industrial scale
- Single & multilayer stacks of AlScN with tunable Sc concentration for piezoelectric modulators
- i-line lithography
- wet chemical etching and dry etching, including deep reactive-ion etching, including deep-reactive ion etching
- Chemical-mechanical polishing
- Fabrication of SAW-modulators on waveguides
- Hermetic opto packaging
- Failure analysis
- Pilot production

Characterization

- Wafer-level characterization of piezoelectric modulators
- Electrical characterization of piezoelectric modulators and AlScN-based SAW on chip-level
- Electro-optical characterization on chip-level with an in-house developed Mach-Zehnder interferometer (cf. Fig.2)

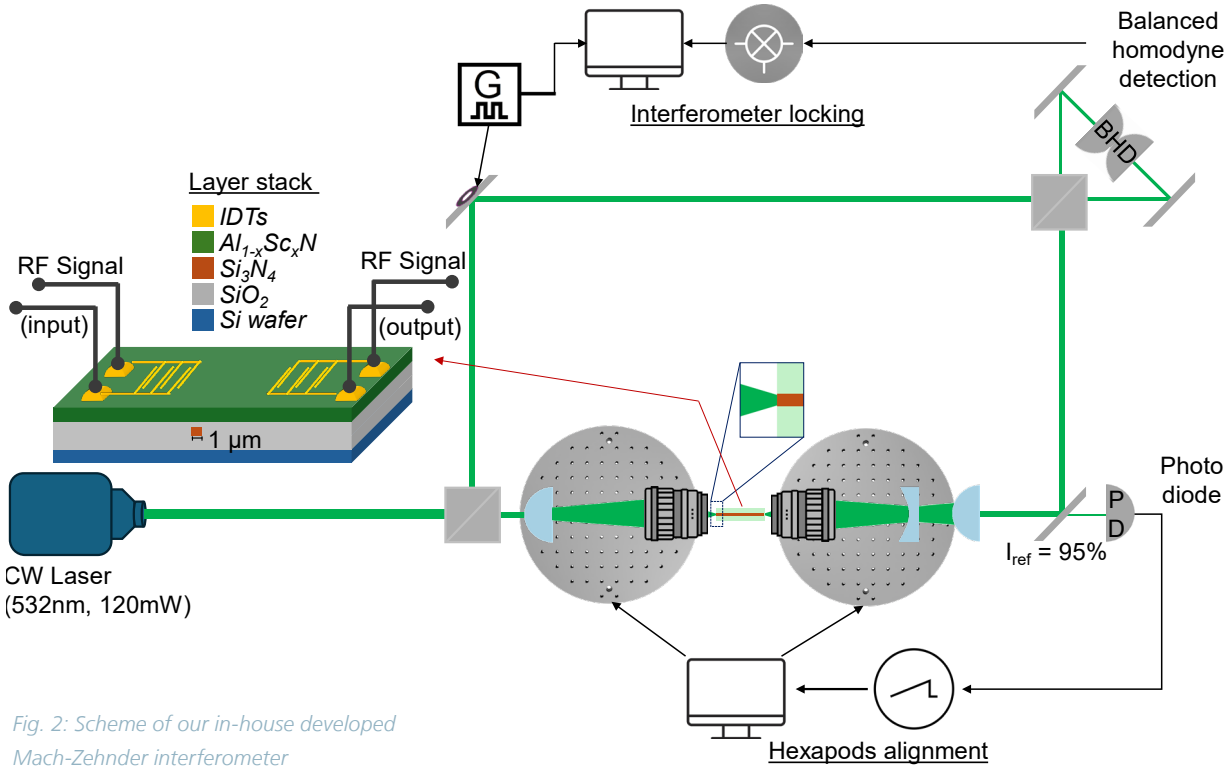


Fig. 2: Scheme of our in-house developed Mach-Zehnder interferometer