Light on a chip - more complex concepts

Hetero- or hybrid PIC, light switching and control, non-linear optical materials

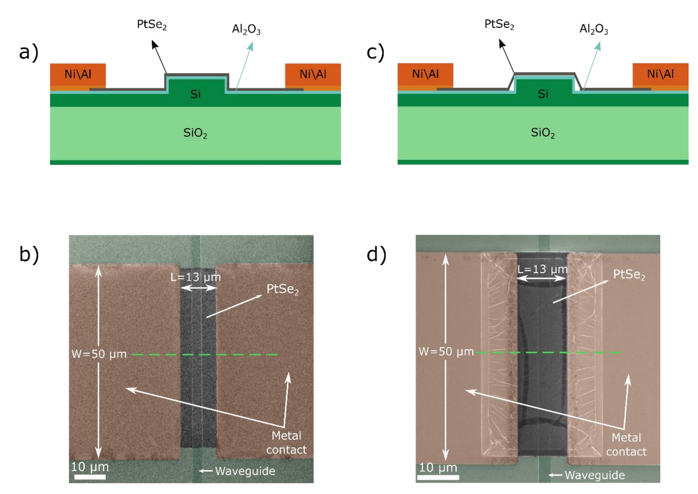
1 Motivation

- Large number of required functions "on-the-chip": photon sources, modulators, frequency converters, detectors, electronic control elements, ...
- “On the chip": coupling losses between the components are eliminated,
- Complex structures → "photonic integrated circuits" (PICs)
- Not all functions can be realized in one material → Hybrid integration

2 Hetero and hybrid PICs

Integration of 2D materials

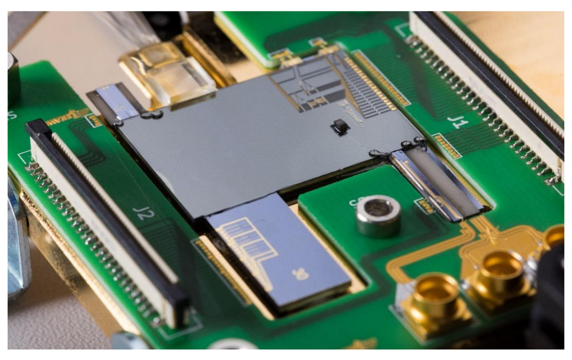
- Almost independent of substrate
- Example: Topography-compliant deposition of platinum diselenide ($PtSe_2$) on SOI waveguides, e.g. as a photodetector, as a heating element



$PtSe_2$ on SOI waveguides, e.g. as a photodetector: topography-conformal deposition (a,b) or by means of transfer with typical defects (c,d).

Hybrid chip-to-chip integration

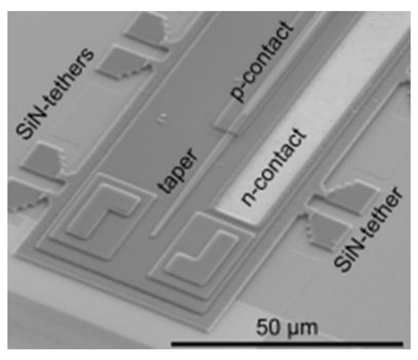
- Optimal combination of active and passive material systems
- Yield management through the use of "known good dies"



Complex hybrid PIC based on Si_3N_4, InP and polymer

Integration of GaAs-based lasers

- Wavelength range: 630 nm - 1180 nm
- Micro-transfer printing of GaAs chiplets on photonic integrated circuits



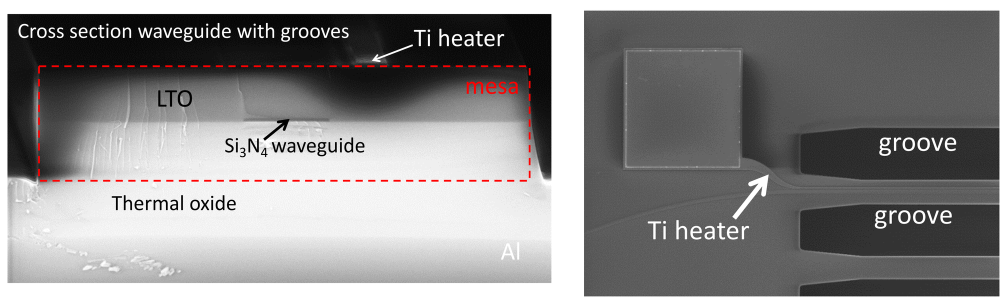
SEM image of a transfer-printable evanescently coupled amplifier chiplet emitting around 950 nm

For „hybrid integration“ see also poster QC08 "Scalable assembly and connection technology"

3 Switching & controlling light

Thermo-optical switches

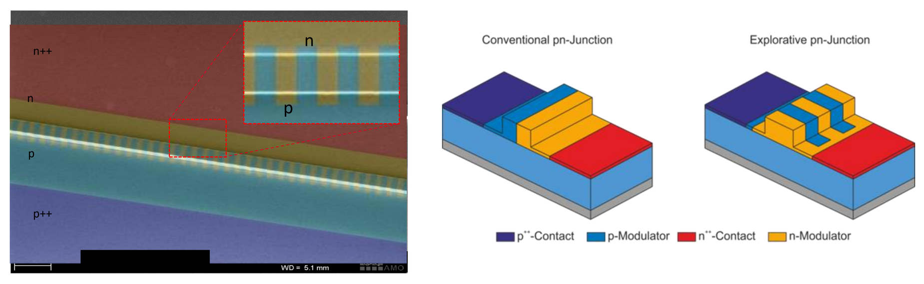
- Simple production, independent of substrate
- Heating wire made of metal or transparent 2D material (e.g. graphene, $PtSe_2$, MoS_2)



(left) Cross-section of a Si_3N_4 waveguide with Ti heating element and trenches for thermal insulation, (right) top view.

Electro-optical charge carrier-based switches

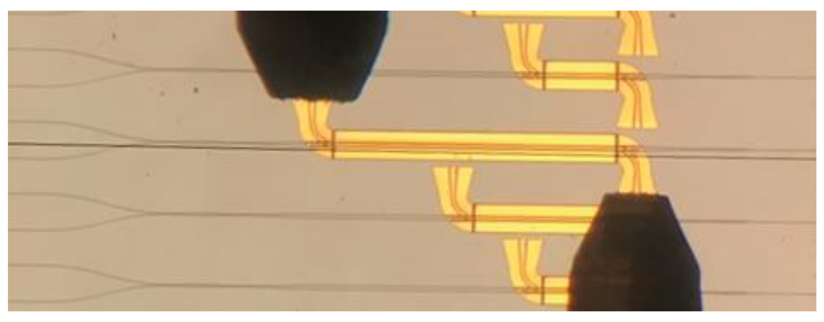
- Injection or depletion type
- Available in SOI or InP
- Fast and energy-efficient, but more complex production than thermo-optical



(left) False color SEM of a depletion modulator: SOI waveguide with interdigitated implantation regions, (right) modulator schematic.

Electro-optical $\chi^{(2)}$-based switching

- Switching and fast modulation via electric field strength
- Available in LNOI and InP

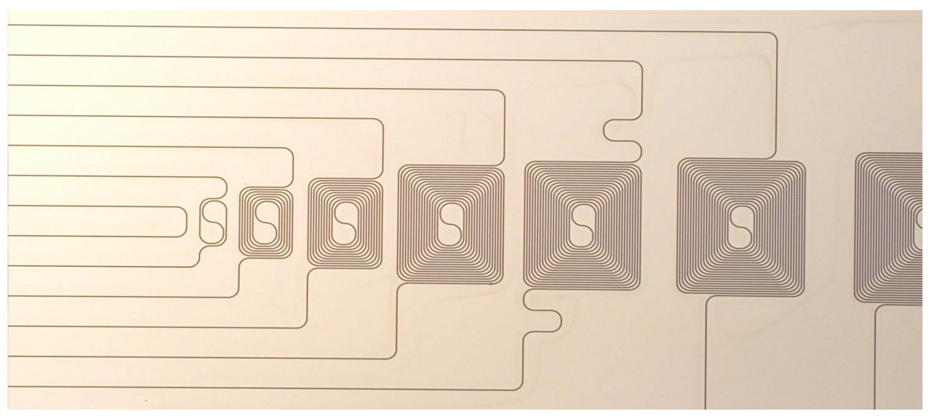


High-frequency modulator in LNOI

4 Nonlinear-optical materials

Aluminum nitride AlN

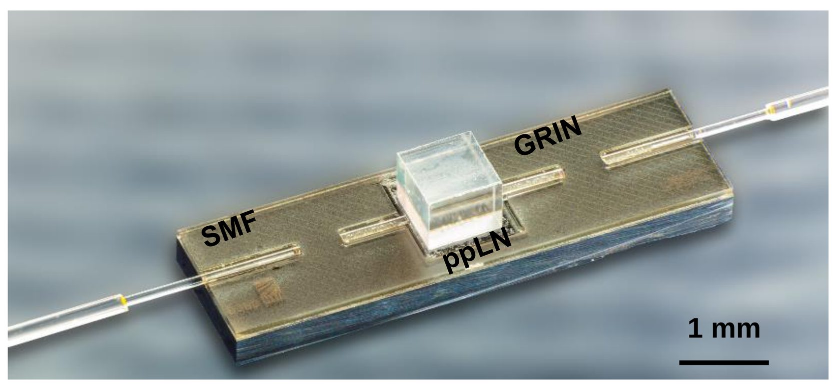
- Waveguide material with $\chi^{(2)}$
- C-axis-oriented growth, e.g. sputtered on sapphire or SiO_2
- Transparency range: UV-C to IR



AlN waveguide with **0.13 dB/cm** loss at 1550 nm

PIC integration of crystals

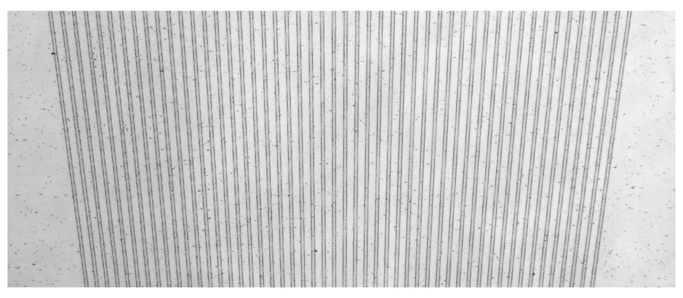
- Integration of classical nonlinear crystals (ppLN, ppKTP, ...) into on-chip free beam regions



PIC with PPLN crystal for SHG and SPDC

Barium magnesium fluoride $BaMgF_4$

- Ultra-wide transparency range
- Quasi-phase matching for frequency conversion across the transparency range possible



Periodically poled fan-out structure in $BaMgF_4$ produced by maskless poling

For inquiries, email us at experts@module-qnc.de

SPONSORED BY THE
Federal Ministry of Education and Research