AlNi-Wave

AlN / Al_2O_3 photonic platform for the blue/UV spectral range

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1 Motivation

- **Increasing the number of qubits** to widen the application scope of quantum computers
- Manipulating qubits in **ion trap based quantum computers** requires precise alignment of different lasers to ions
- Free space optics: not scalable, limited to 10 to 100 light-ion interaction zones
  - Large volumes required
  - Difficult to integrate into cryostats
  - Needs realignment
- Solution via **integrated photonics**: fiber array coupling, light splitting and routing on-chip
- Requires highly efficient waveguides from infrared until 370 nm (UV): few choices exist
- Aluminum nitride (AlN) and aluminium oxide (Al_2O_3) are promising candidates
- In *AlNi-Wave* we are aiming for the **best AlN waveguides with Al_2O_3 cladding** which can also benefit from the 2nd order nonlinear optical coefficient of AlN

2 Innovation

Fraunhofer IAF

- Sputtered AlN with excellent quality (lowest oxygen levels, epitaxial growth on suitable substrates, highest crystalline quality)
- "Influence of growth temperature on the properties of aluminum nitride thin films prepared by magnetron sputter epitaxy", *J. Appl. Phys.* 134, 185107 (2023)

AMO GmbH

- Made waveguides with AlN from Fraunhofer IAF, achieving record low propagation loss in telecom spectrum (polycrystalline AlN on SiO_2, no cladding)
- "Sputtered aluminum nitride waveguides for the telecommunication spectrum with less than 0.16 dB/cm propagation loss", *Opt. Express* 32(26), 46522 (2024)

***AlNi*-Wave goals**

Optimize AlN growth & waveguide process

- For lowest propagation losses in the visible to blue/UV spectrum
- For epitaxial growth on sapphire
- With Al_2O_3 cladding
- With surface roughness **<0.3 nm** (RMS)

Target waveguide propagation loss <**3dB/cm** at **397 nm** wavelength

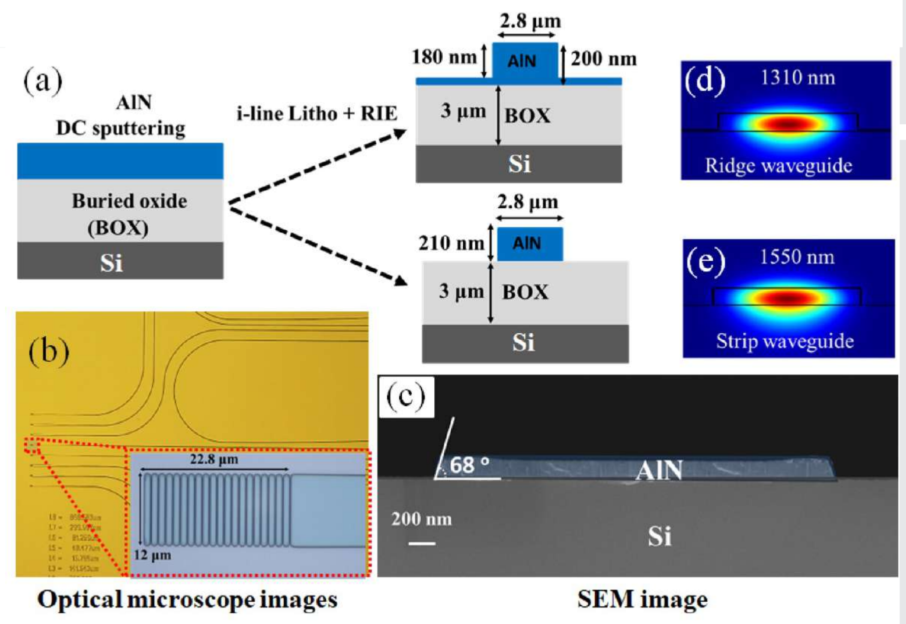


Fig. 1. (a) AlN waveguide fabrication process flow, resulting in two different waveguide cross sections. (b) Optical image of the fabricated grating coupler and waveguides. (c) Representative cross-sectional SEM image. (d) and (e) represent the mode profile of the TE_0 mode for the Ridge waveguide at 1310 nm and the Strip waveguide at 1550 nm, respectively.

3 Future performance profile & skills of the project partners

PTB

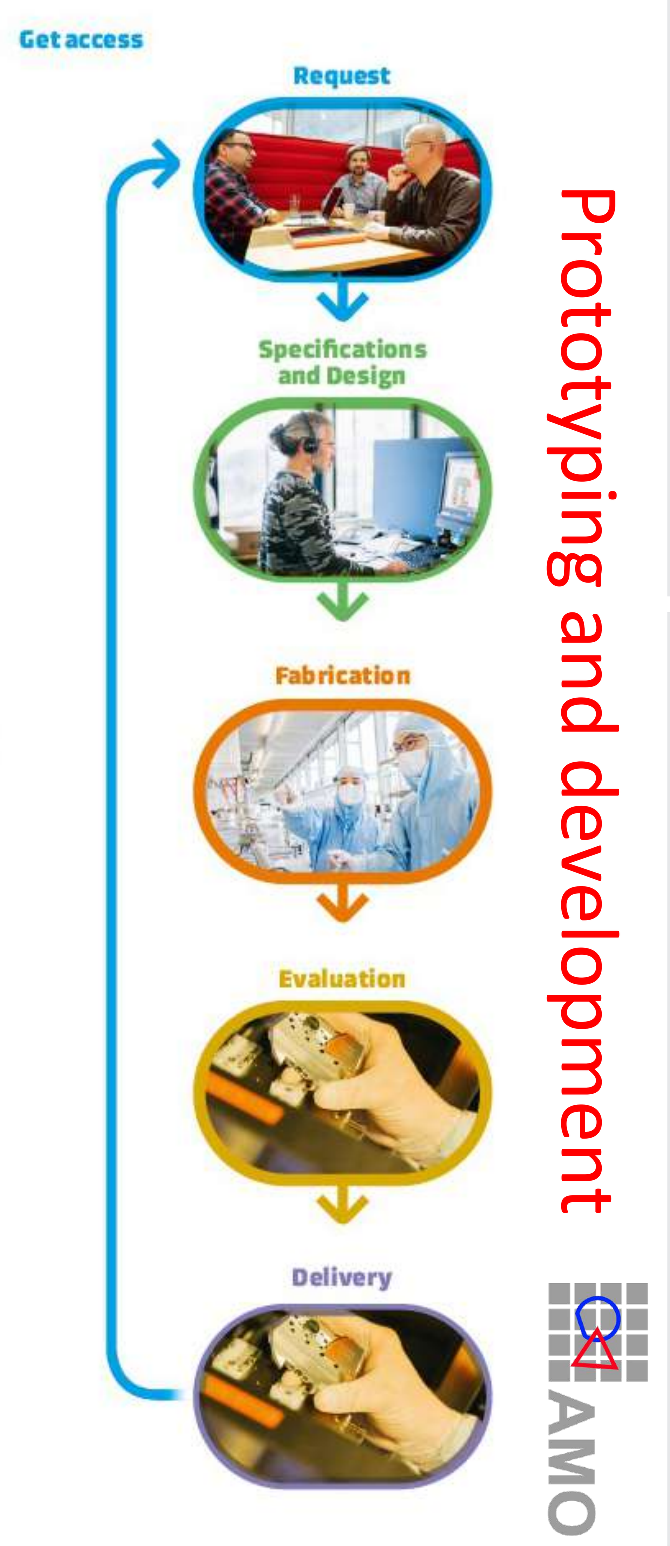
Simulating, designing and preparing integrated photonics for use in **follow-up R&D projects** on realizing ion trap based quantum computers.

AMO GmbH

New process as a building block for contract research via the AMO Services and research projects: low loss waveguides for the blue/UV spectrum have various applications beyond ion trap based quantum computing → see Prospects

Fraunhofer IAF

Participating in **R&D projects** and future **commercial offering** of optimized AlN wafers.



4 Prospects

- Our work may yield the **best AlN waveguides** → use in **follow-up projects** for ion trap based quantum computers
- Startup **Qudora** as associated partner
  - Consider our planned waveguide configuration as one of the most promising for Ion Trap based Quantum Computers
  - Aiming for 10 – 30% market share in ion trap based quantum computers by 2030
- **Further applications** of our waveguides:
  - Ultra-fast Pockels-modulators or switches for telecommunication or light routing
  - Biosensing and spectroscopy with blue/UV fluorescence excitation
  - Optics for augmented reality
  - Higher harmonic generation

PTB Physikalisch-Technische Bundesanstalt Nationales Metrologieinstitut

AMO

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