

# **Optical MEMS - Light Modulation & Steering for Quantum Computing**



MEMS Spatial Light Modulators (SLMs) 3

- Addressing & positioning atomic qubits
- Trap structures

Processors for linear optical

quantum computing

- Multiplexer
- Modulators
- Aberration control

Beam tracking

 $\bullet$ 

- Generation of optical tweezers
- Generation of structured light

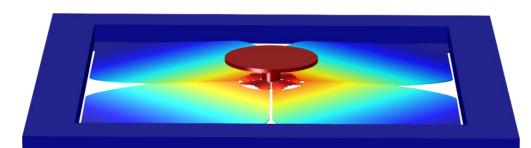
#### **MEMS** Mirror 2

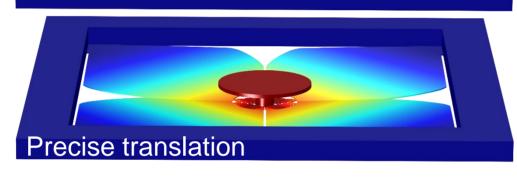
## Performance

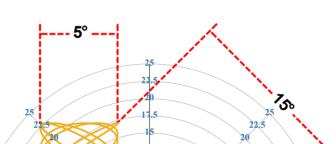
- Deflection from sub pm to 100+ µm
- Tilt angles up to  $\bullet$ 
  - 30° TOSA quasi-static  $\bullet$
  - 90° TOSA resonant  $\bullet$
- Aperture 0.4 mm to 8 mm

# Features

- nm precision in up to 3 axes
- Position sensors and feedback loop
- static, dynamic







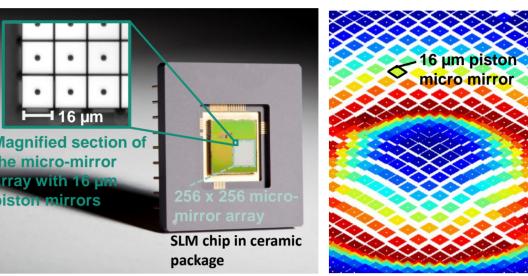
Displaceable scanning region

Micro-mirror array based SLMs enable fast & precise amplitude and phase modulation down to deep UV.

# Features of the technology:

- Application specific design
- High pixel count
- Precise analogue modulation
- Fast kHz MHz frame rates
- Broad application wavelengths: deep UV  $\rightarrow$  near IR

Towards a scalable addressing technology for atomic qubits with transitions in the UV In the QNC-Space project "SMAQ", Fraunhofer IPMS and the Max Planck Institute of Quantum Optics further developed the piston MEMS SLM technology and demonstrated its potential for the generation of tweezer arrays in the UV.



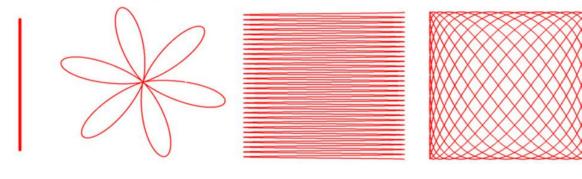
Phase modulating MEMS SLM with approx. 65,000 individually controllable piston micro-mirrors.

**Deflected** piston micro-mirrors. Image recorded with White Light Interferometry.

A Future Perspective: Neutral atom quantum	Twezzer arrays generated
computer & simulator capable of working	with a UV laser and piston
in the UV	MEMS SLM
Atoms 5 µm	triangular
arranges in	50 μm <b>322 nm</b>
a register Piston mirror MEMS-SLM for beam shaping in the UV	honeycomb
	50 μm <u>322 nm</u> 50 μm <u>322 nm</u>

A) Neutral atom quantum simulator (adapted from [1]) with a piston MEMS SLM, illustrated after [2]. **B)** Tweezer arrays generated with a piston MEMS SLM at 322 nm (QNC-Space Project SMAQ)

- and resonant operation
- Flexible Raster- and  $\bullet$ Lissajous scan patterns
- Displaceable illumination region for selective scanning

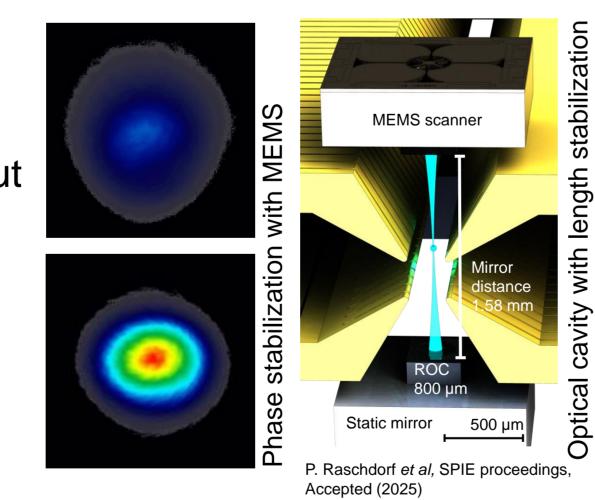


Different scan trajectories

### **Current developments**

High piezo drive forces

- Phase stabilization of laser
- Optical cavity with actively stabilized length for Qubit readout



Long-term stability

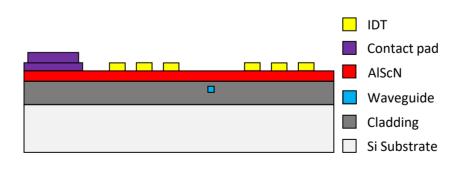
#### Integrated MEMS Photonics 4

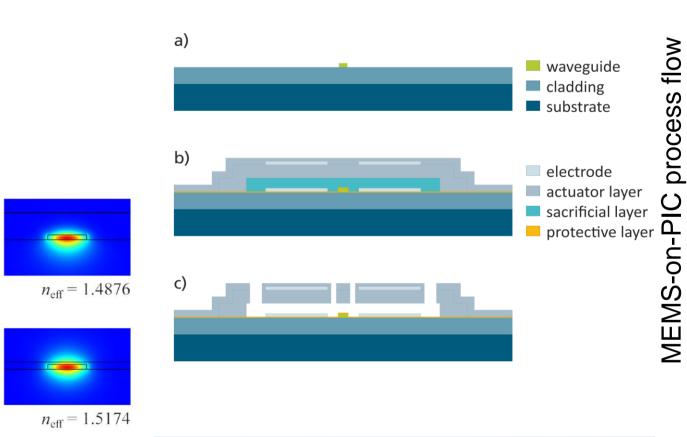
# **MEMS-on-PIC technology**

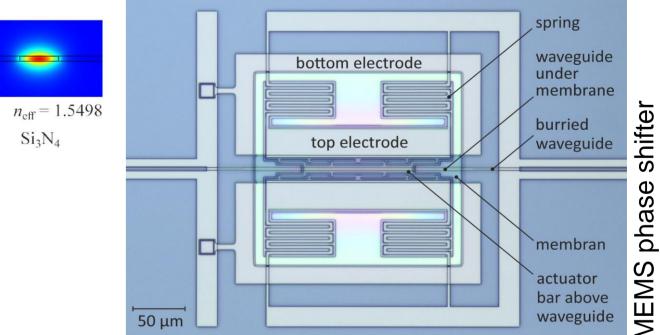
- MEMS phase-shifter for photonic integrated circuits
- Voltage < 10 V
- Power  $\ll 1 \,\mu W$
- No crosstalk
- Cryo-compatible

# SAW modulated waveguide

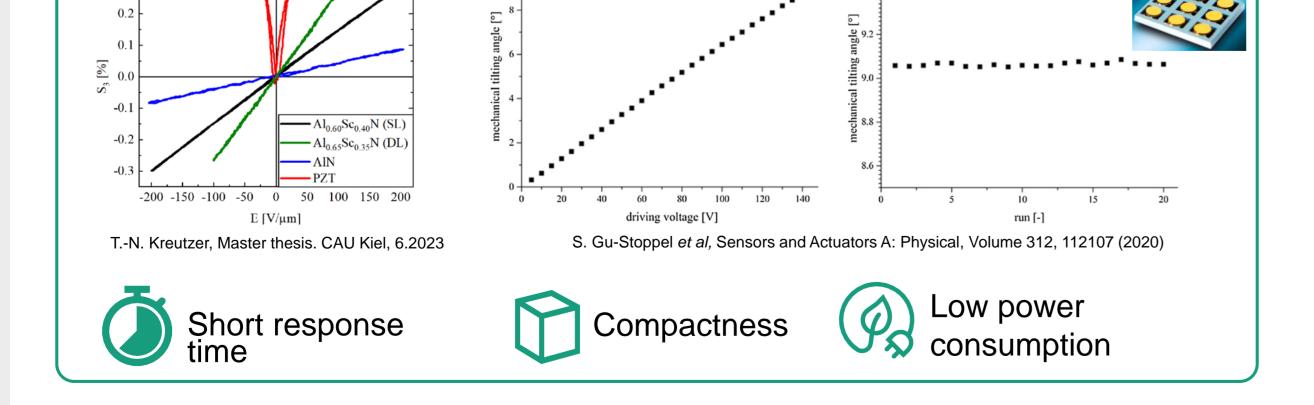
- Phase modulation
- AIScN based SAW
- SiN waveguide



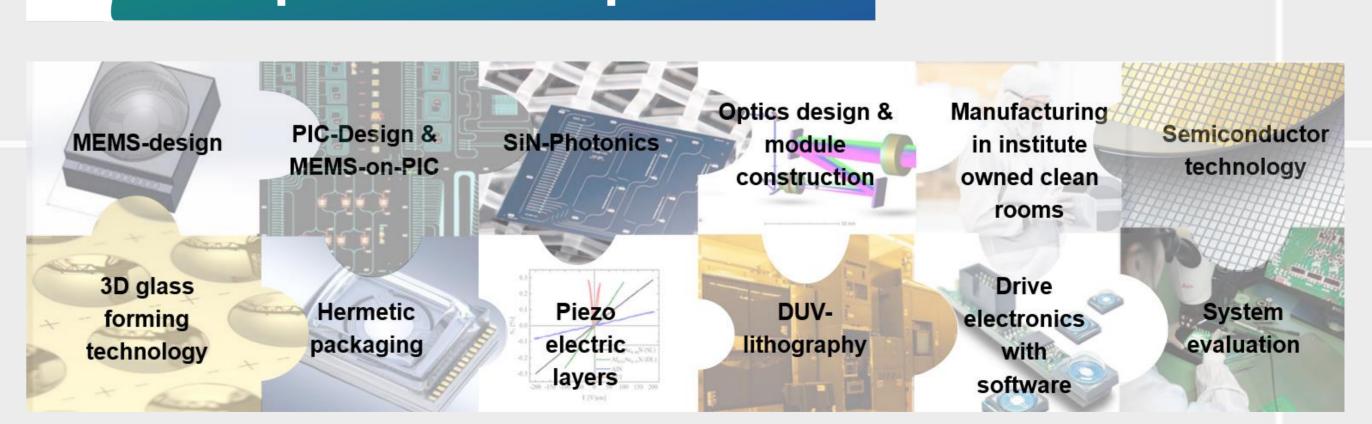




#### **Complete MEMS pilot line** 5



Linearity



Si<sub>3</sub>N<sub>4</sub>

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