Development of the Micro-opto-electromechanical Modulator for Cryogenic Applications

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Motivation

Research in the field of quantum computing and quantum information has shown that the use of quantum effects can significantly improve the performance of computing systems when solving problems in the statistics, computing and communications. In it is turn, the desire for miniaturization has led to the quantum optical integrated circuits currently being developed.

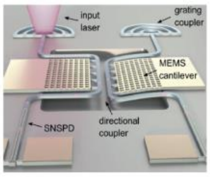
Logical operations are then implemented by controlling the optical path of photons and using integrated active optical components. Currently widely used thermo-optical modulators introduce cross-thermal interference, require large amounts of energy and are ineffective at cryogenic operating temperatures. Alternative are electro-optical modulators with the active length is thousands of micrometers, making it difficult to use such modulators in scalable applications.

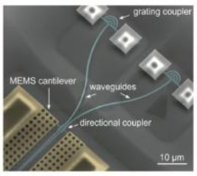
The use of micro-opto-electromechanical modulators allows minimizing the footprint without reducing the relative efficiency of the device

Object of research

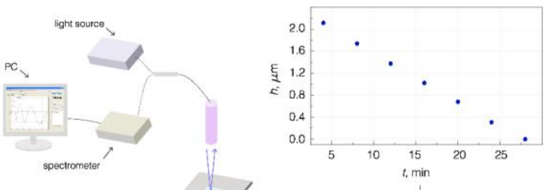
The main parts of modulator: silicon nitride waveguide, electrodes (necessary to physically change the boundaries of the waveguide) and active part formed by selective silicon oxide etching.

When voltage is applied, a force begins to act on the electrodes, proportional to the square of the voltage and inversely proportional to the distance between the electrodes. By controlling the voltage, displacement amplitude of the moving electrode and the waveguide connected to it can be adjusted.





Determination of etch rate



SiO_2 etch velocity in HF acid solution : $\vartheta \approx 90$ nm/min

Acknowledgment

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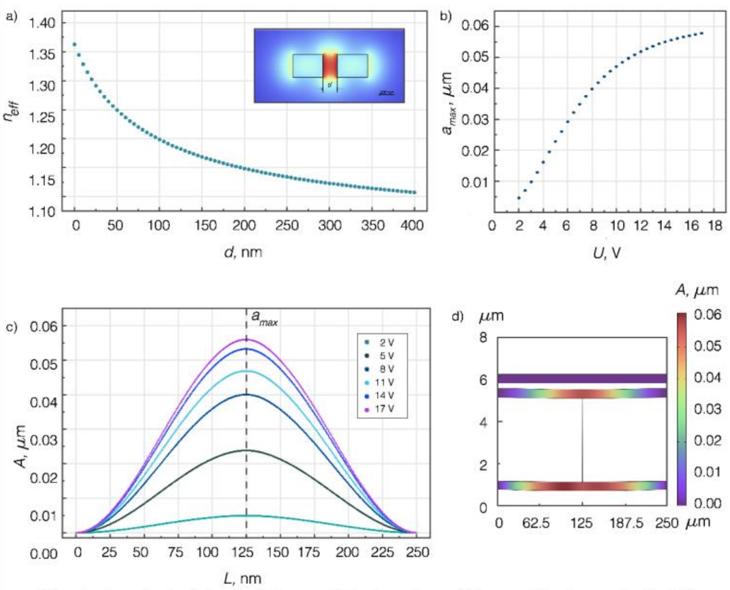
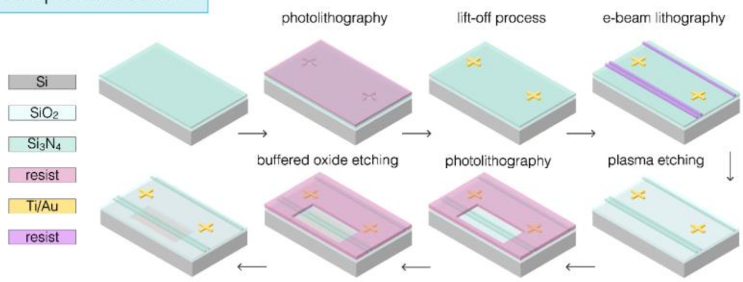
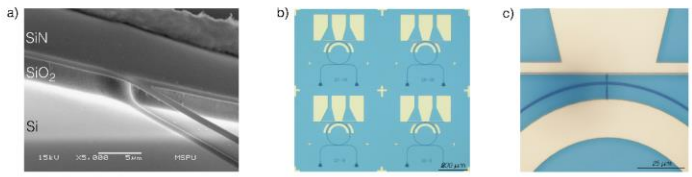
Numerical Simulation by using COMSOL Multyphysics



a) The effective refractive index of a slot waveguide in dependence of the gap width at a wavelength 1550 nm. Mode profile is shown in the inset (d=200 nm)
b) An maximum amplitude displacement in reliance of the applying voltage
c) An electrode amplitude displacement in dependence of applying voltage
d) Colormap of electrode amplitude displacement (voltage value is 17 V)

Sample fabrication





a) Microphoto of the suspended part was formed by using HF acid solution
b) Microphoto of fabricated devices
c) Microphoto of the fabricated device

Conclusion

MOEM modulator is a promising alternative to electro-optical modulator in cryogenic applications that impose stringent requirements for device footprint. However, fabrication of MOEM modulator is a difficult technological issue due to additional parts are required to form the active part of the modulator

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