The Ultimate Limit of Photonic Scaling

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Abstract: Half a century of photonic research has led to a remarkable scaling of photonic footprint. We will review current state-of-the art photonic devices and discuss recent advances in the field, including novel plasmonic devices and the emergence of new class of atomic scale devices.

Scaling photonics devices towards a smaller footprint is a technological challenge. A challenge however, that might pay off with devices operating at higher speed, lower power consumption and with devices at an unmatched density.

Photonics has come a long way. In the early days of photonics - and to this very day - photonics often relies on assembling free space optical components into a larger system. Yet, only integrated optics offers optical devices with stable operation and economics of costs. And indeed, by now, integrated optics is dominating the communications, the sensing and entertainment markets, i.e. the markets where cost and scaling matter. And despite of the success integrated optical elements are not yet at the same scale as electronic components. As an example we will review the optical modulator. The optical modulator is a key element in every high-speed communications link. It is used to encode electrical signals onto an optical carrier. So far, the majority of optical modulators rely on the proven $LiNO_3$ technology. These modulators have footprints in the order of cm^2. Fortunately, a few years ago, more compact silicon, InP and GaAs based modulators have emerged. These devices feature footprints in the order of mm^2 [1-3]. Yet, complementary metal-oxide semiconductor electronics (CMOS) house hundreds of transistors on a single □m^2, making a co-integration of today's silicon MZMs with CMOS electronics impractical [4]. In pursuit of more compact silicon modulators, various approaches have been demonstrated. E.g. resonant ring modulators [5, 6] – which, however only work at discrete frequencies. Recently, plasmonics has drawn significant interest as an alternative solution [7, 8]. And indeed, novel plasmonic-organic hybrid modulators have demonstrated modulators with footprints in the order of □m^2, electrical bandwidths way above 100 GHz with power consumption in the fJ/bit that operate across all optical wavelengths [9], see Fig. Most recently, a new generation of atomic scale switches has been introduced [10]. These devices depend on relocating a single atom or at most a few atom and thereby switching a plasmonic switch from the on- to the off-state and the other way round [10, 11]. We will conclude our talk by reviewing this new technology.

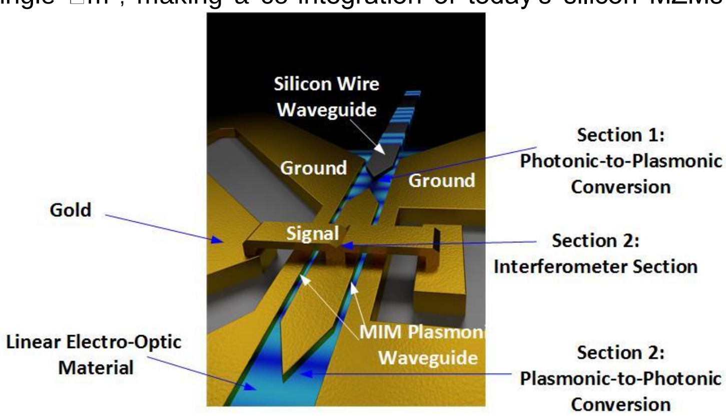

Fig. Plasmonic Mach-Zehnder modulator with 10 µm length. The plasmonic interferometer is formed by the metallic island and the metallic contact pads. An electrical signal can be applied to the island via a

Acknowledgements: Partial funding through the ERC Plasilor, the FF-Photon and SNF project precoR is acknowledged.

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