2D photonic nanojet via Bloch surface wave: limitations and beyond

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Microstructures, e.g., microspheres, can generate a highly confined beam propagating over several wavelengths while maintaining a sub-λ beam size. It is a well-known nonresonant phenomenon that appears for a wide range of diameters of microspheres, from approximately 2λ to 40λ. Chen *et al.* first reported this phenomenon and named it *photonic nanojet* (PNJ) in 2004 [1]. Recently, the PNJ generation has been demonstrated using non-circular geometries in 3D like micro-pyramids and rectangular pillars, and it has been also applied to 2D surface waves *via* surface plasmon polariton (SPP) [2]. In this study, we propose a new host of PNJs in 2D surface wave implementation. Bloch surface wave (BSW) is a dielectric analogue of SPPs, which is an electromagnetic surface wave excited at the interface between a truncated periodic dielectric multilayer and a surrounding medium. Dielectric materials assures low optical loss and longer propagation of BSWs, reported, but not limited, up to 2.5 mm [3]. In addition, design flexibility of the 2D system allows arbitrary shapes of optical elements, which is advantageous compared to the constraints in 3D micro-fabrication.

The schematic of the BSW platform with elements under study is shown in Fig 1(a). The operation wavelength is 1.55 μm. By chemical vapor deposition, six periods of Si_3N_4 (n_1 = 1.79) and SiO_2 (n_2 = 1.45) are alternately deposited on a glass substrate. For the top layer, an additional 50-nm-thick layer of Si_3N_4 is deposited. On the top of the platform, 60-nm-thick TiO_2 (n_s = 2.23) is additionally patterned for the element structures, the fabrication details are reported elsewhere [3]. Numerical studies are carried out using a commercial FDTD tool (CST microwave studio). We employ scanning near-field optical microscopy (SNOM) for experimental verifications. When the BSW illuminates a TiO_2 microdisk, as the scenario shown in Fig. 1(b), the expected PNJ does not arise. The reason is that the effective refractive index contrast is too low, i.e., Δn = 0.15 [3]. The goal of our study is to surmount this limitation by shape changes, and to obtain a tightly confined beam like PNJs. Avoiding too complex structures, we vary the element shape, e.g., ellipse, rhombus, and triangle. Among them, the isosceles triangle of base = 10 μm and altitude = 14 μm, shown in Fig. 1(d), leads to the smallest spot, whose FWHM size reaches 0.62λ. In the conference, we will present beam properties depending on shape changes and corresponding experimental results measured by SNOM.

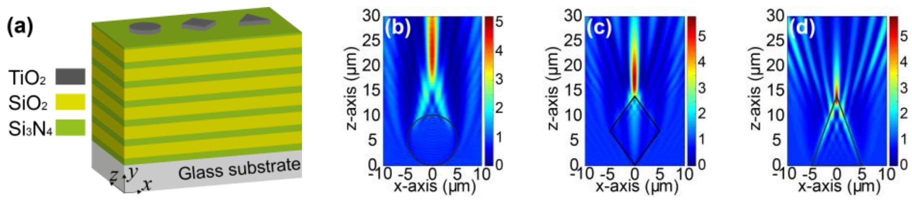

Fig. 1: (a) Schematic of BSW platform with investigated TiO_2 elements. FDTD simulation results for the intensity distributions: (b) a microdisk of diameter = 10 μm, (c) a rhombus of diagonals of 10 μm and 14 μm, and (d) an isosceles tringle of base = 10 μm and altitude = 14 μm.

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