Microfabrication of cylindrical structures by proton beam writing for photonic nanojets formed in different media

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In the micro to nano-scale world, an interaction between light and microstructure leads to various fascinating phenomena and opens the broader fields of study. In 2004, Chen et al.[1] used a finite-difference time-domain simulation and showed a high intensity focused electromagnetic beam with a width below the diffraction limit by plane-wave illuminating on a dielectric microcylinder. This sub-wavelength waist and non-evanescent beam, namely photonic nanojet (PNJ), has demonstrated applications of interest such as super-resolution microscopy[2] and nanofabrication[3].

With the help of microfabrication, the PNJ generation can be achievable since the size of scattering element is the same order as the wavelength of incident light[4]. We utilized the MeV proton microbeam to produce microcylinders with smooth sidewalls and characterized corresponding PNJ properties[5] with the in-house confocal laser scanning microscope[6]. On the other hand, the refractive index of medium surrounding the microstructure also affects the PNJ profiles e.g. PNJ distribution or shape[1]. Thus, investigating the effects of refractive index and microcylinder's geometry is necessary to step towards the practical implementations.

In this work, the proton beam writing system at Shibaura Institute of Technology was employed to fabricate PMMA microcylinders on a glass substrate. The PNJ main characters were evaluated in air ($n_{air} \approx 1$) and distilled water ($n_{water} \approx 1.33$), which are common media of applications, as shown in Figure 1. A distribution of PNJ formation clearly changed as the embedded media changed. The different characteristics due to the geometry and the surrounding media will be discussed to explore the applicability and limitation in the future.

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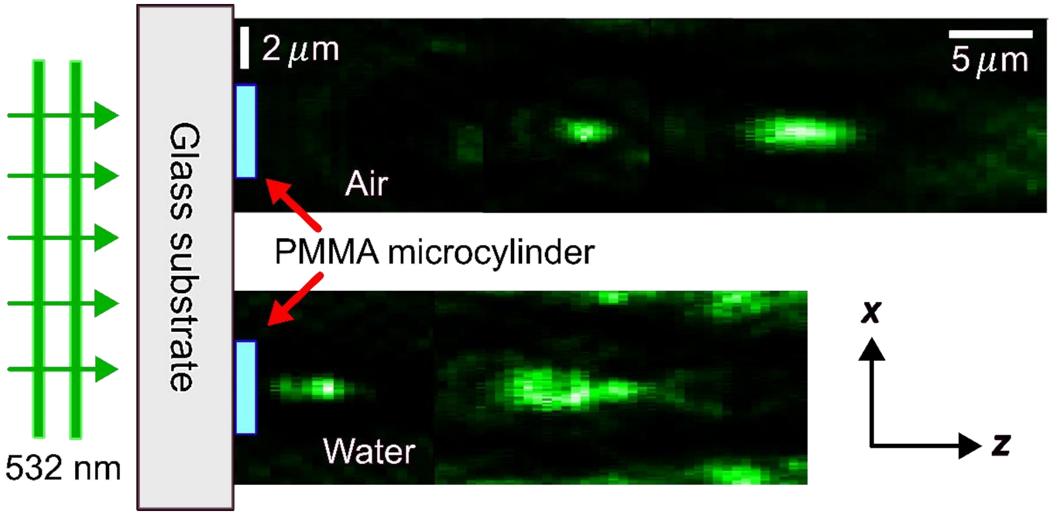

Figure 1: The schematic of photonic nanojets (PNJs) formed by microcylinders. The PMMA film was deposited on the glass substrate and a thickness of approximately 2.7 μm was obtained. Then, the microcylinder was patterned by 1-MeV proton beam writing at Shibaura Institute of Technology. The formation of PNJs was observed by 532-nm laser scanning confocal microscope at Mie University[6]. The reconstructed confocal microscope images of PNJs are exemplified with the 4.5-μm diameter microcylinder in air and distilled water media. The multiple data were stacked to show the whole PNJs generation. Preliminary results clearly illustrate different characteristics of PNJs owing to the media refractive index which is one of the important parameters regarding different applications of interest. Noted, the microcylinders and imaged PNJs are scaled with x-axis and z-axis scale bars of 2 μm and 5 μm, respectively.