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THE OPERATIONAL MODE OF OPTICAL MICROSCOPE APPLYING PHOTONIC JET MICROSCOPY

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ABSTRACT

The previous experimental research on microsphere parameters applying photonic jet microscopy in free space revealed if the relative indexes come near two, it needs larger microspheres. It also means if the relative indexes come near to one, it needs a smaller microsphere. In addition to these premises, the mode of ordinary optical microscope introducing photonic jet microscopy in its operation must be taken into account. That includes the light source or filter and the fluidic environment - free space or immersion oil. These additional modes are predicted in two-dimensional finite element method calculation, which leads to the more practical use of photonic jet microscopy in the near future; that is in free space using visual-light sources with the ratio of refractive indeces getting near to two will gain larger image magnification.

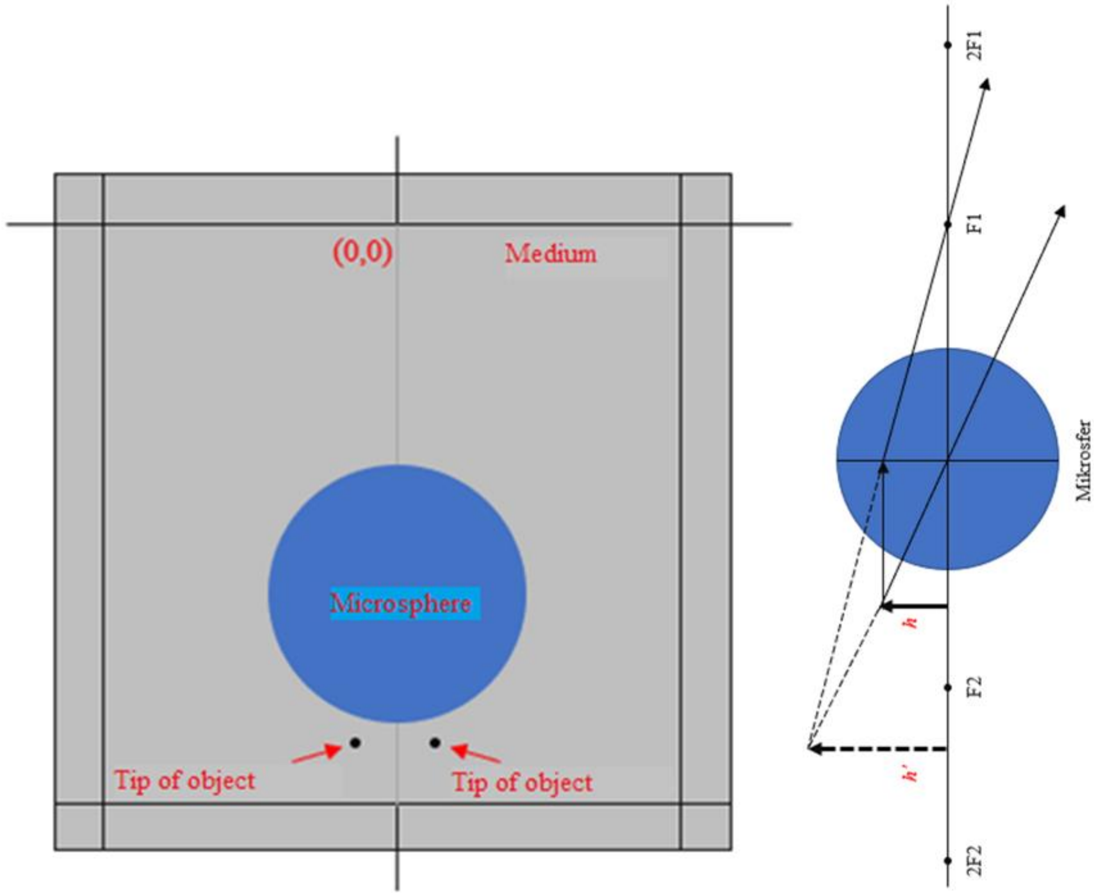
Keywords: photonic jet, microscopy, optical microscope, microsphere

INTRODUCTION

Concerning the photonic jet phenomenon [1, 2], there are many potential applications that have been proposed [2], including enlargement/enhancement of the image of submicron objects using an optical microscope [3]. In laboratory practices, the operational mode of these optical microscopes applying photonic jet is either by putting the microspheres and the object in free space or in immersed liquid [3, 4]. We have demonstrated the operational mode in free space by lying some microspheres on the top of the observed object, which is concurrent with our calculations [5-7]. However, these operational modes are not so operationally practiced. For example, it is not a straightforward practice to put a microsphere directly on the destinated object mechanically without scratching the surfaces. However, some fellow researchers have also come out with ideas estimating the object position relatives to the center of microspheres, rational to the wavelength of operating light, as the function of microsphere's refractive index [8]. These researches regarding the photonic jet effect in microscopy, especially finding the optimum modes, including the material parameters of microsphere and environment, are still obsessing for operational practice. It is simply due to the size. The microsphere can not be considered as a classical lens.

METHOD

There were two materials considered as the microsphere, i.e., soda-lime glass (n_g = 1.5) and barium titanate (n_{bt} = 1.9). For simulations, the light-source was varied in the wavelengths of white light-spectrum from violet to red, i.e.: violet (415 nm), dark-blue (450 nm), light-blue (473 nm), green (533 nm), yellow (580 nm), light-orange (600 nm), dark-orange (605 nm), pink (685 nm), and dark-red (750 nm). We also varied the diameter of microspheres into 5, 10, 25, 40, 42, 83, 88, 98, and 120 µm; and the medium were air (n_a = 1), water (n_w = 1.3) and immersion-oil (n_{io} = 1.5). These components are arranged as FIGURE 1. Before we calculated the magnifications yielded by each microsphere in each medium for each visible light wavelength, first we collected the parameters of the photonic jet as mentioned in the previous study [9] and depicted in a previous analysis [10].



(a) (b)

FIGURE 1. The microsphere was arranged geometrically in 2D inside a medium surrounded by perfectly matched layers as in (a). The gap between tips of objects represents the object (h); each tip emits an electrical field at a designated wavelength, at a distance of 10 nm from the microsphere's surface. This geometrical arrangement simulates the generation of virtual image (h') if the object located near the surface of microsphere; as in (b). This virtual image is considered as an object observed by the objective lens.

RESULT AND DISCUSSION

In principle, the simulations designed to calculate the magnification generated by a microsphere in free space. The object's size (h) in FIGURE 1(b) was simulated as the gap between tips of object (FIGURE 1(b)). When the virtual image (h') is emerged in the simulations, the magnification can be calculated right away using a simple calculations $M = h'/h$.

Commonly, the operational mode of an optical microscope is in free space. But in some cases, the object is needed to be immersed in water or oil. Thus, our objective is to see which parameters will bring the maximum magnification when a microsphere was added. FIGURE 2 shows image magnification, yielded using barium-titanate microsphere in free-space, as a function of microsphere diameter for each light-source is concerned that is visible-light spectrum. As for other mediums, water, and immersion oil, the smallest is immersion oil. So that can be said that the relative refractive index closer to 2 will yield larger magnification. On the contrary, the relative refractive index closer to 1 will yield a smaller magnification.

FIGURE 2 also presents the largest magnification yielded when the light-source is yellow (580 nm) at the center of the spectrum. However, the magnifications resolution is worse as the diameter is getting larger. It is can be explained by FIGURE 3, showing the focal distance (the position of photonic jet's maximum intensity from the microsphere surface) is more spread out under visible light illumination when the diameter of the microsphere is getting larger.

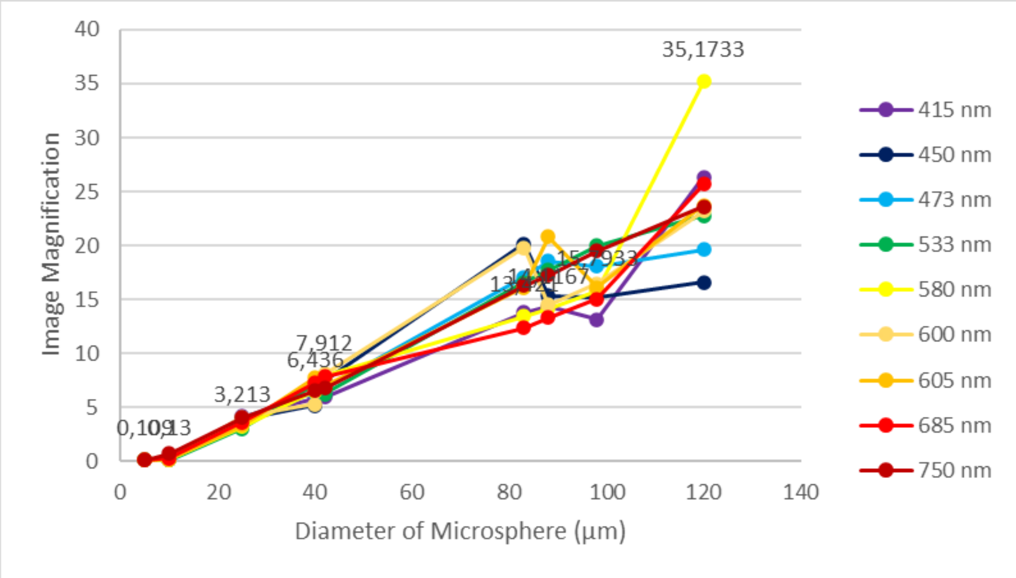


FIGURE 2. Image magnification as a function of microsphere's diameter for each light-source in visible light spectrum using barium titanate microsphere in free-space. The largest magnification is yielded when the light-source has a wavelength of 580 nm (yellow).

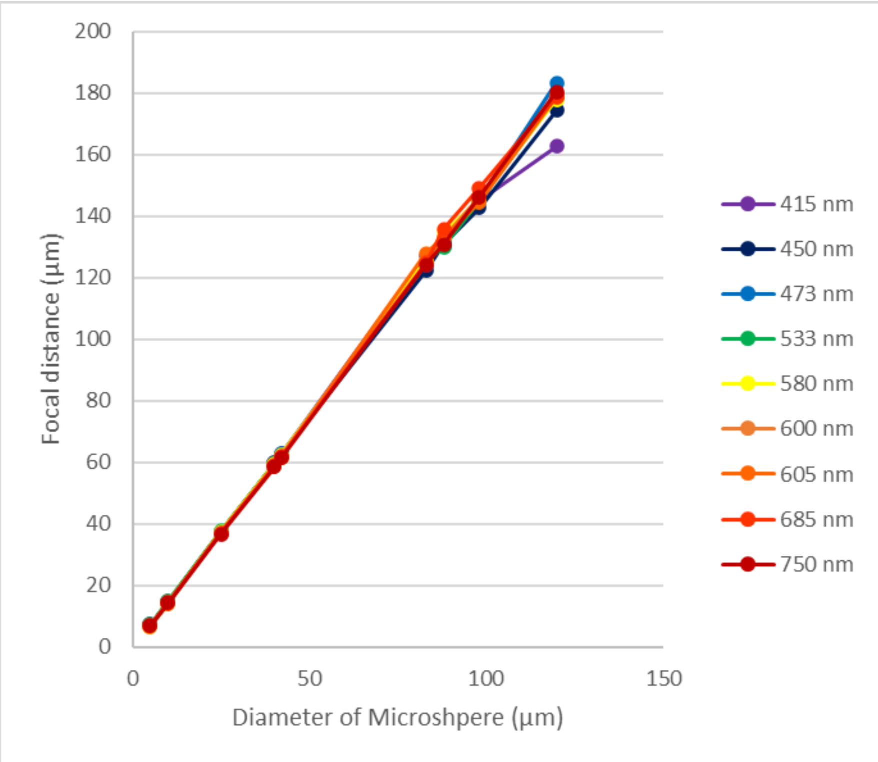


FIGURE 3. The position of maximum intensity of photonic jet (focal distance) generated by a barium titanate microsphere when illuminated by visible light as a function of the diameter of microsphere.

Even though soda-lime glass microspheres do not yield image magnification as large as barium titanate does, they also have a smaller numerical aperture than barium titanate¬'s, making barium titanate microsphere can visualize finer details than soda-lime microsphere with a smaller numerical aperture. Our calculations using soda-lime glass (FIGURE 4) emphasize our previous publications [5, 6] and experiment results in the laboratory, also other's [11]; that is worth to mention: soda-lime glass microsphere yield the largest image magnification using the diameter of 25 µm.

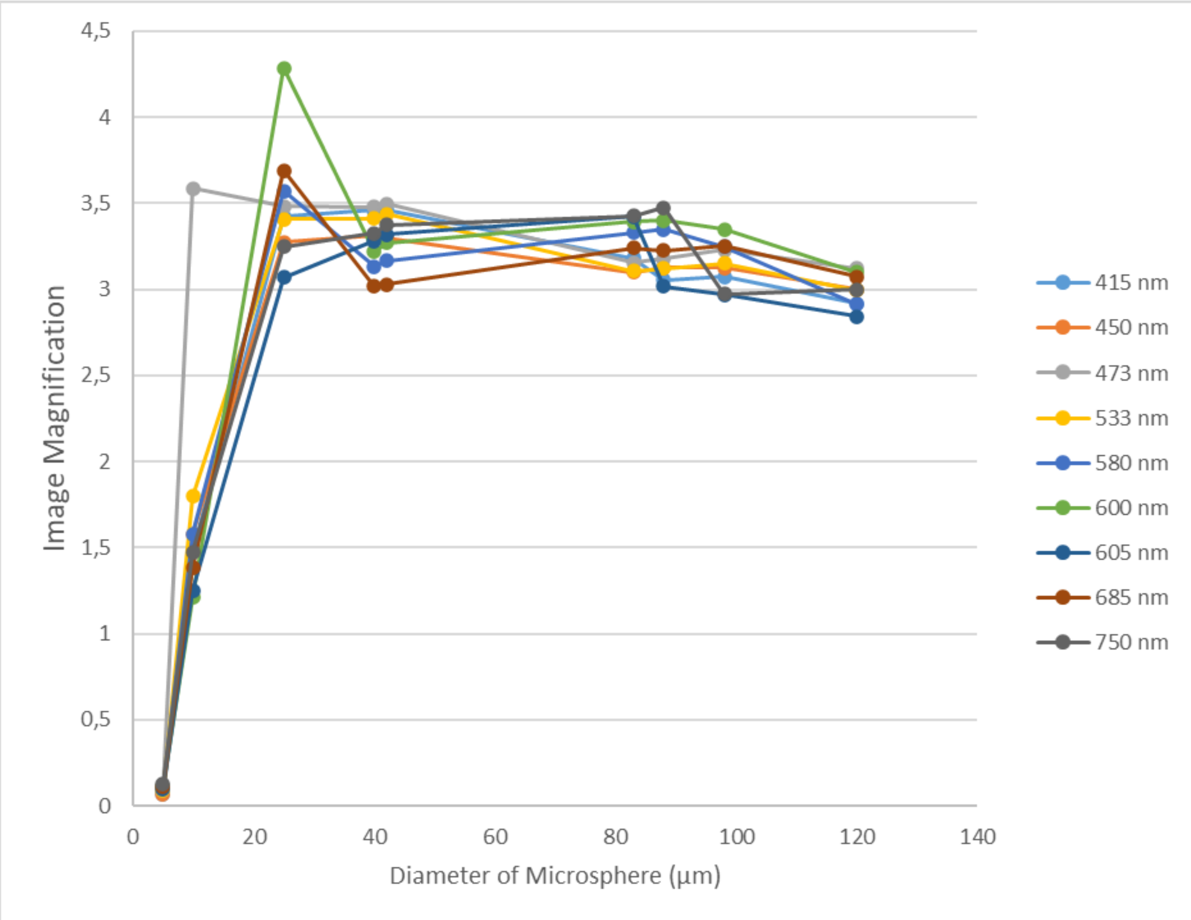


FIGURE 4. Image magnification as a function of microsphere's diameter for each light-source in visible light spectrum using soda-lime glass microsphere in free-space

CONCLUSION

A standard optical microscope may apply the photonic jet phenomenon to gain larger image magnification by putting a microsphere before the object. The relative refractive index between the microsphere and medium close to two can generate larger image magnification when a visual-light source is applied.

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REFERENCES

[1] Z. G. Chen, A. Taflove and V. Backman, “Photonic nanojet enhancement of backscattering of light by nanoparticles a potential novel visible-light ultramicroscopy technique,” *Optics Express*, vol. 12, no. 7, pp. 1214-1220, 2004.

[2] A. Heifetz *et al*., “Photonic Nanojets,” *Journal of Computational and Theoretical Nanoscience*, vol. 6, no. 9, pp. 1979-1992, 2009.

[3] L. Li e*t al*., “Label-free super resolution imaging of adenoviruses by submerged microsphere optical nanoscopy,” *Light Science and Amp. Applications*, Original Article, vol. 2, p. e104, 2013.

[4] S. Lee *et al*., “Immersed transparent microsphere magnifying sub diffraction limited objects,” *Applied Optics*, vol. 52, no. 30, pp. 7265-7270, 2013.

[5] A. Abdurrochman *et al*., “Observing micro meter object using photonic jet,” *Journal of Physics, Conference Series*, vol. 1080, no. 1, p. 012051, 2018.

[6] A. Abdurrochman *et al*., “A Potential Application of Photonic Jet in Observing Micro-Metric Materials,” *Materials Science Forum*, vol. 966, pp. 507-511, 2019.

[7] A. Abdurrochman *et al*., “The experimental quest on dimension and material of microsphere for photonic jet microscopy,” *Journal of Physics, Conference Series*, vol. 1568, p. 012002, 2020.

[8] S. Lecler *et al*., “Photonic jet lens,” *Scientific Reports*, vol. 9, no. 1, p. 4725, 2019.

[9] D. McCloskey *et al*., “Controlling the Properties of Photonic Jets,” *in 12th International Conference on Transparent Optical Networks (ICTON)*, Munich GERMANY, Jun 27-Jul 01 2010.

[10] A. Abdurrochman *et al*., “Photonic jet etching Justifying the shape of optical fiber tip,” *AIP Conference Proceedings*, vol. 1712, p. 030001, 2016.

[11] A. Leong Hoi *et al*., “High Resolution Microsphere Assisted Interference Microscopy for 3D Characterization of Nanomaterials,” *physica status solidi*, vol. 215, no. 6, p. 1700858, 2018.