Nanoscale

Supplementary

Frozen Matrix Hybrid Optical Nonlinear System Enhanced by Particle Lens

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Table S1: Summary of Nonlinear Coefficients

Material Type	Wavelength of Z-scan	Dispersion Matrix	Pulse Duration	Nonlinear Coefficients	Reference
Au	532 nm	Silicate Glass	120 fs	-7.0 cm/GW	S. L. Qu, Y. W. Zhang, H. J. Li, J. R. Qiu, C. S. Zhu, *Opt. Mater.*, 2006, **28**, 259-265
Silver	795 nm	Water	110 fs	8 cm/GW	R. A. Ganeev, M. Baba, A. I. Ryasnyansky, M. Suzuki, H. Kuroda, *Opt. Commun.*, 2004, **240**, 437-448
Silver	532 nm	Silicate Glass	120 fs	19.3 cm/GW	S. L. Qu, Y. W. Zhang, H. J. Li, J. R. Qiu, C. S. Zhu, *Opt. Mater.*, 2006, **28**, 259-265
Cu	800 nm	Water	120 fs	-2.36×10^{-3} cm/GW	G. H. Fan, S. T. Ren, S. L. Qu, Q. Wang, R. X. Gao, M. Han, *Opt. Commun.*, 2014, **330**, 122-130
Cu	800 nm	Alcohol	120 fs	-3.74×10^{-3} cm/GW	G. H. Fan, S. T. Ren, S. L. Qu, Q. Wang, R. X. Gao, M. Han, *Opt. Commun.*, 2014, **330**, 122-130
Graphene Oxide	800 nm	Water	120 fs	-2.5×10^{-2} cm/GW	X. L. Zhang, Z. B. Liu, X. C. Li, Q. Ma, X. D. Chen, J. G. Tian, Y. F. Xu, Y. S. Chen, *Opt. Express.*, 2013, **21**, 7511-7520.

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Graphene Oxide Synthesis

Firstly, $NaNO_3$ and graphite were mixed inside the concentrated H_2SO_4 solution. By vigorous stirring, $KMnO_4$ was added into the suspension followed by the addition of H_2O_2 to trigger the chemical reduction reaction. The mixture was kept at 90 °C. When the reaction was completed, the product was washed and dried. After the purification, the GO sheets were obtained and dispersed inside DI water.

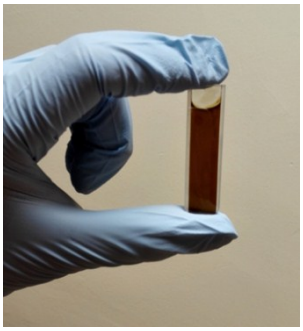

Fig. S1. Optical image of the Graphene Oxide dispersion

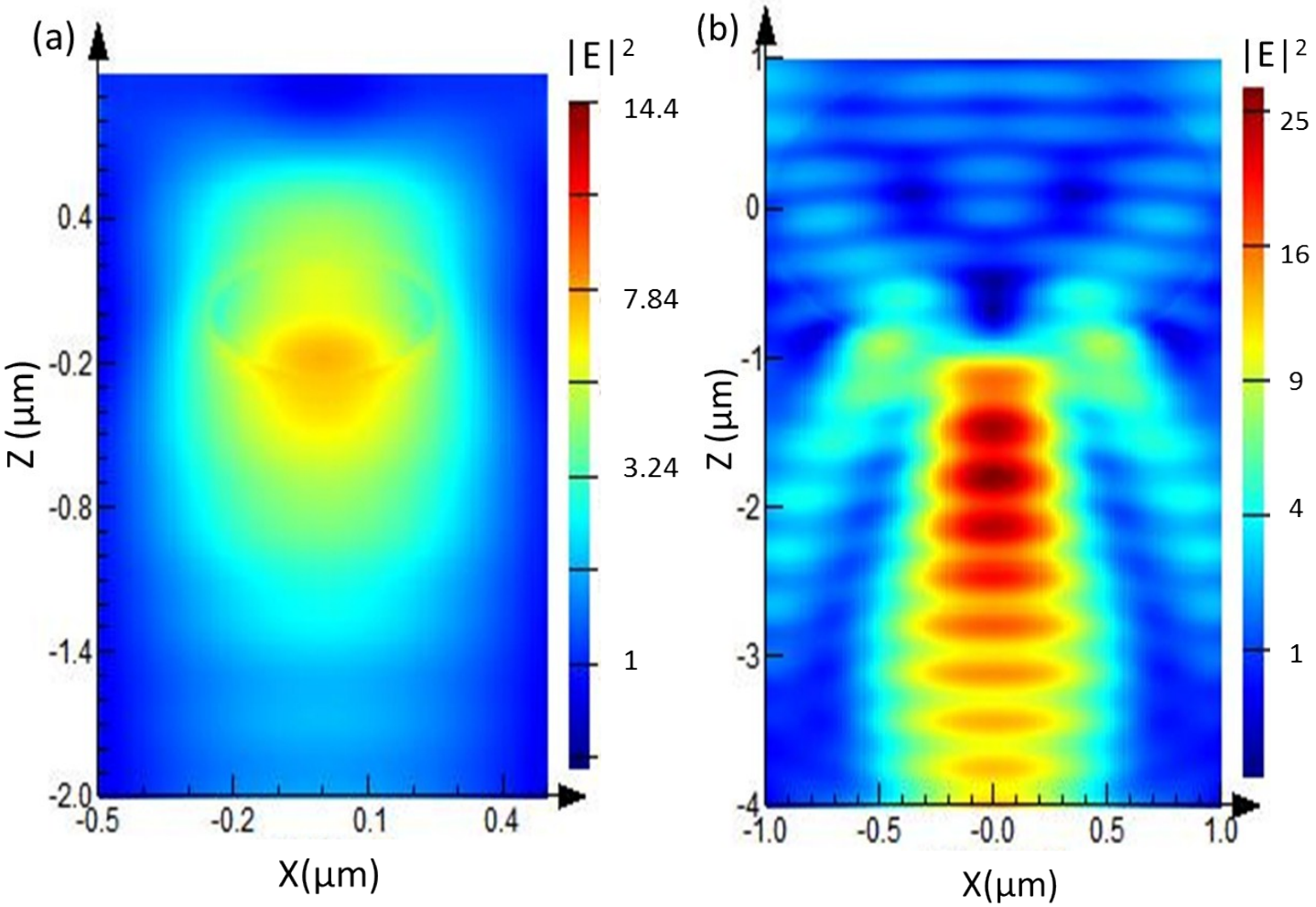

Fig. S2. FDTD simulation results for SiO_2 micro-bead with (a) 500 nm and (b) 2µm diameters in frozen matrix (ice)

SiO_2 Micro-bead Precipitation Study

SiO_2 micro-bead dispersion in water was injected into a glass cell. The cell was aligned vertically. The time was counted for the SiO_2 micro-bead to fully precipitate to the bottom. The precipitation speed can be calculated (precipitation distance of the cell divided by the time of precipitation). It was found the precipitation speed of the SiO_2 micro-bead is ~83.3 μm/s. In the nonlinear absorption characterization, the laser spot on the sample is ~34 μm (diameter). The size of the melting area is comparable to the size of the laser spot. As a result, once the matrix was melt, it took very short time for the SiO_2 micro-beads in this area to precipitate. The experiment took a much longer time and it can be confirmed that the SiO_2 micro-beads mostly precipitated once the matrix was melt.

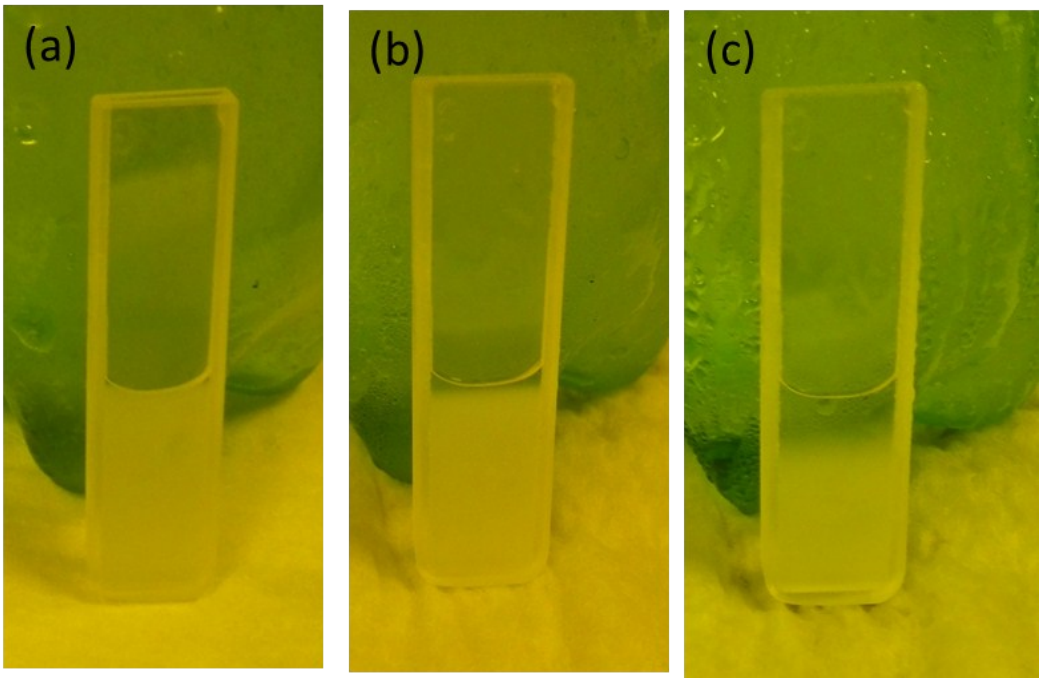

Fig. S3. Optical image for the SiO_2 micro-bead dispersion at the precipitation time of (a) 4 minutes, (b) 10 minutes, and (c) 60 minutes

SiO_2 Micro-bead Precipitation Study

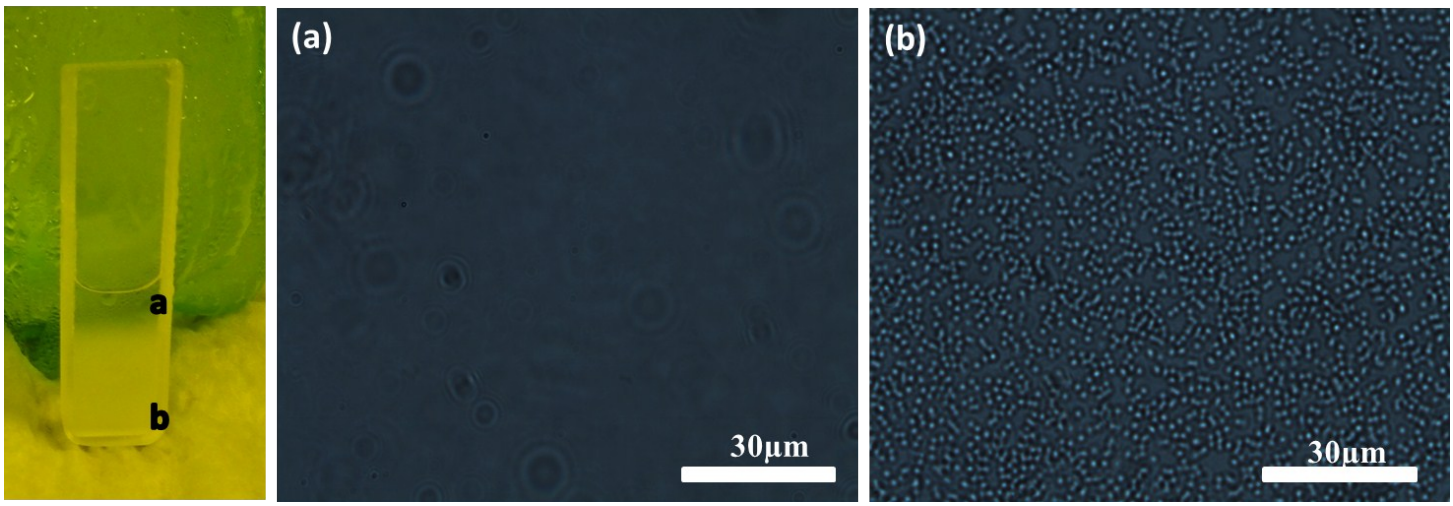

Fig. S4. Optical microscope images of the dispersion in (a) upper solution and (b) bottom solution. It can be seen from the image that after precipitation, most of the SiO_2 micro-beads resides in the bottom where the solution looks opaque. On the other hand, the upper part is free of the SiO_2 micro-beads and looks transparent.

Z-scan Measurement for Water and SiO_2 micro-beads

It shows that there is no nonlinear response for water and SiO_2 micro-beads

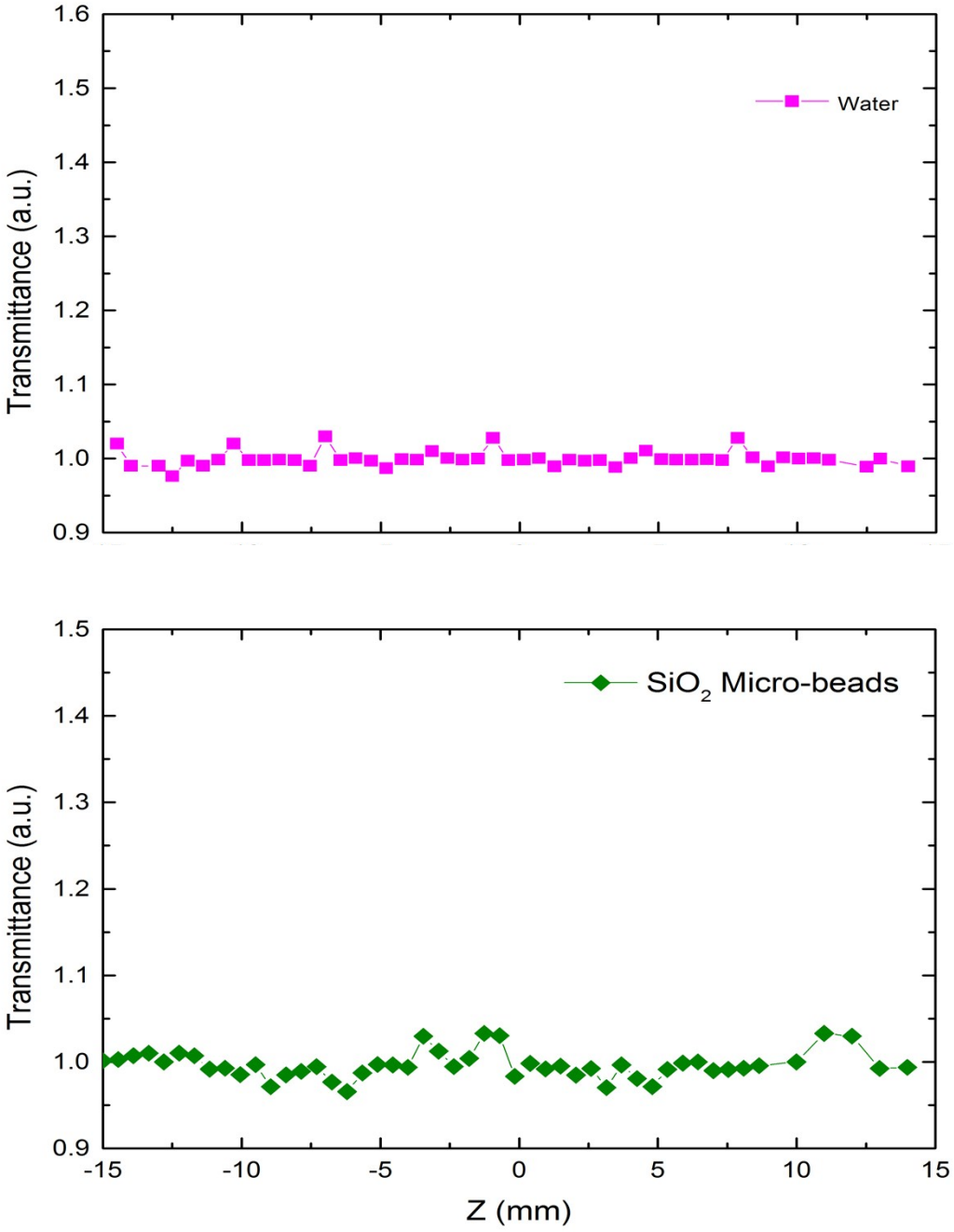

Fig. S5. Open aperture Z-scan results for the (a) water and (b) SiO_2 micro-beads