Generation of copper nanoparticles induced by fs-laser irradiation in borosilicate glass

Juliana M. P. de Almeida, Leonardo De Boni, Waldir Avansi, Antonio Carlos Hernandes, Cleber Renato Mendonça

São Carlos Institute of Physics - USP

Outline

- Why obtain nanoparticles in glass?
- Why using fs-laser micromachining?
- Goal
- Material and methods
- Results
- Conclusions

Why obtain nanoparticles in glass?

- Local field enhancement effect

- They are promising materials for photonic applications once they can exhibit ultrafast response times and high third order nonlinearities

Why using fs-laser micromachining?

Advantages:

- Spatial control of the nanoparticles formation in the micrometer scale;

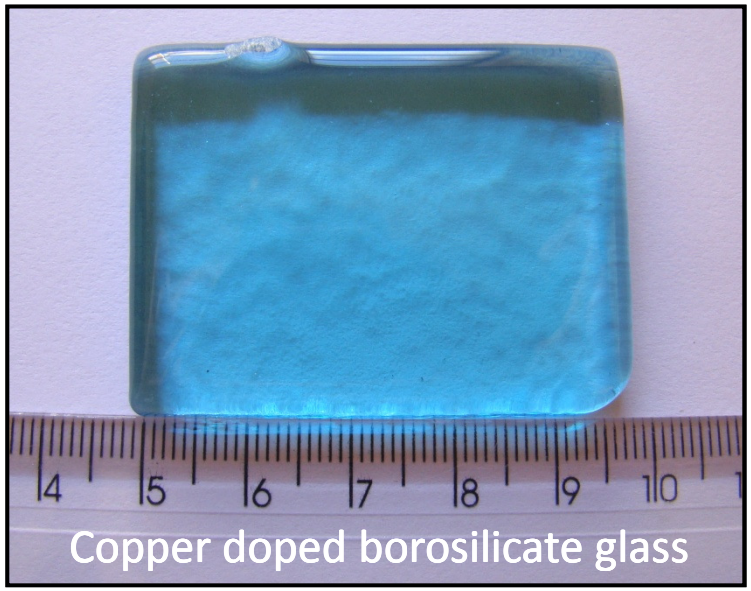
- Obtaining metallic nanoparticles in confined regions at the surface or into the bulk of the materials;

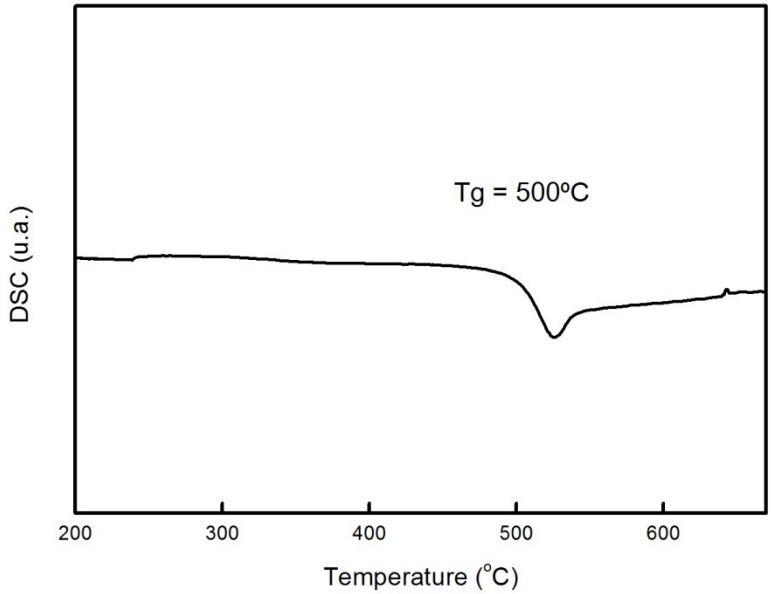
- Development of photonic devices with high third order nonlinearities and ultrafast response times;

Purpose

The purpose of this study was to produce and control copper nanoparticles at small regions on the surface and inside a borosilicate glass

Material



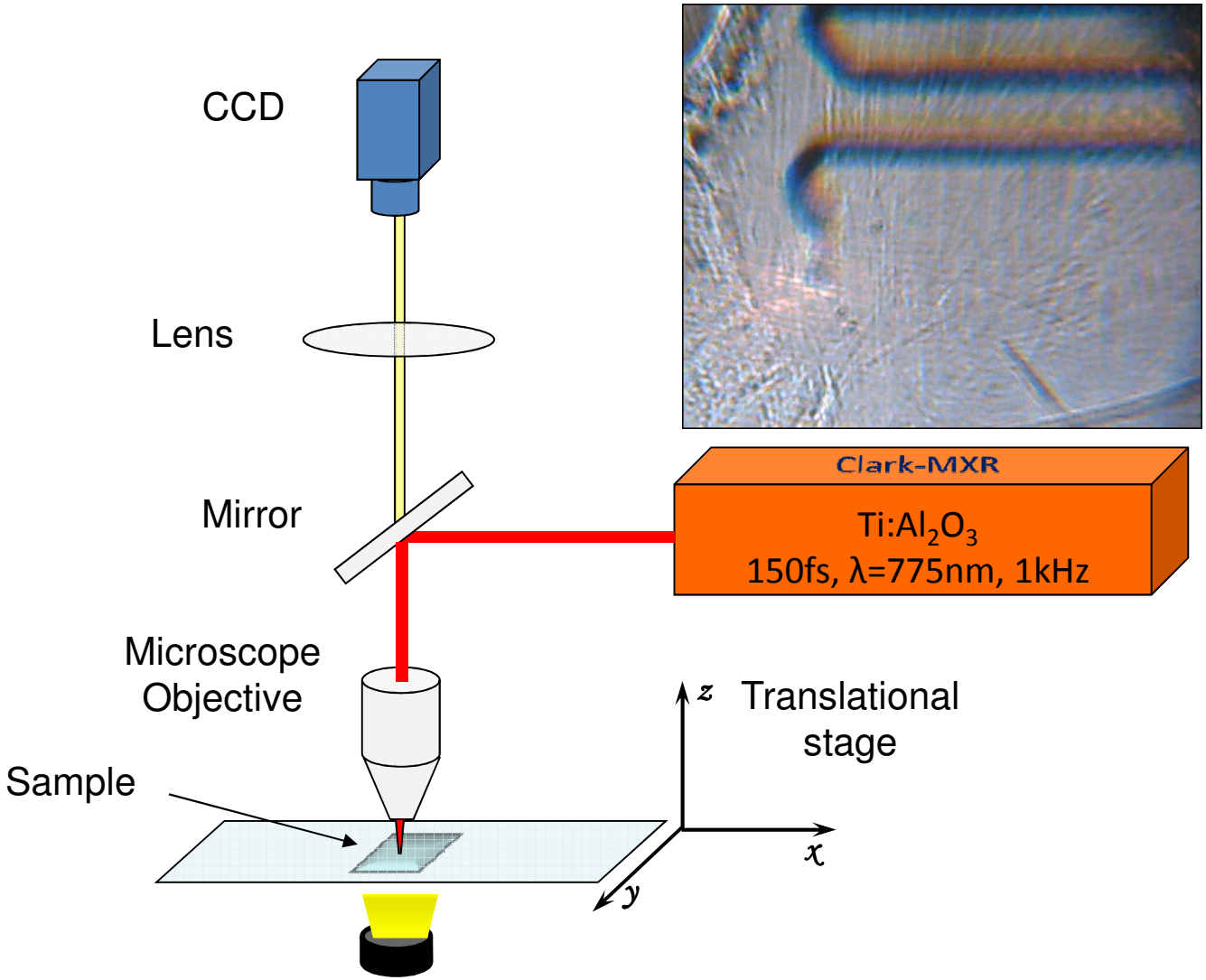


$(50SiO_2 - 17B_2O_3 – 11{,}5MgO – 10Na_2O – 11{,}5\ Al_2O_3):0{,}1CuO$

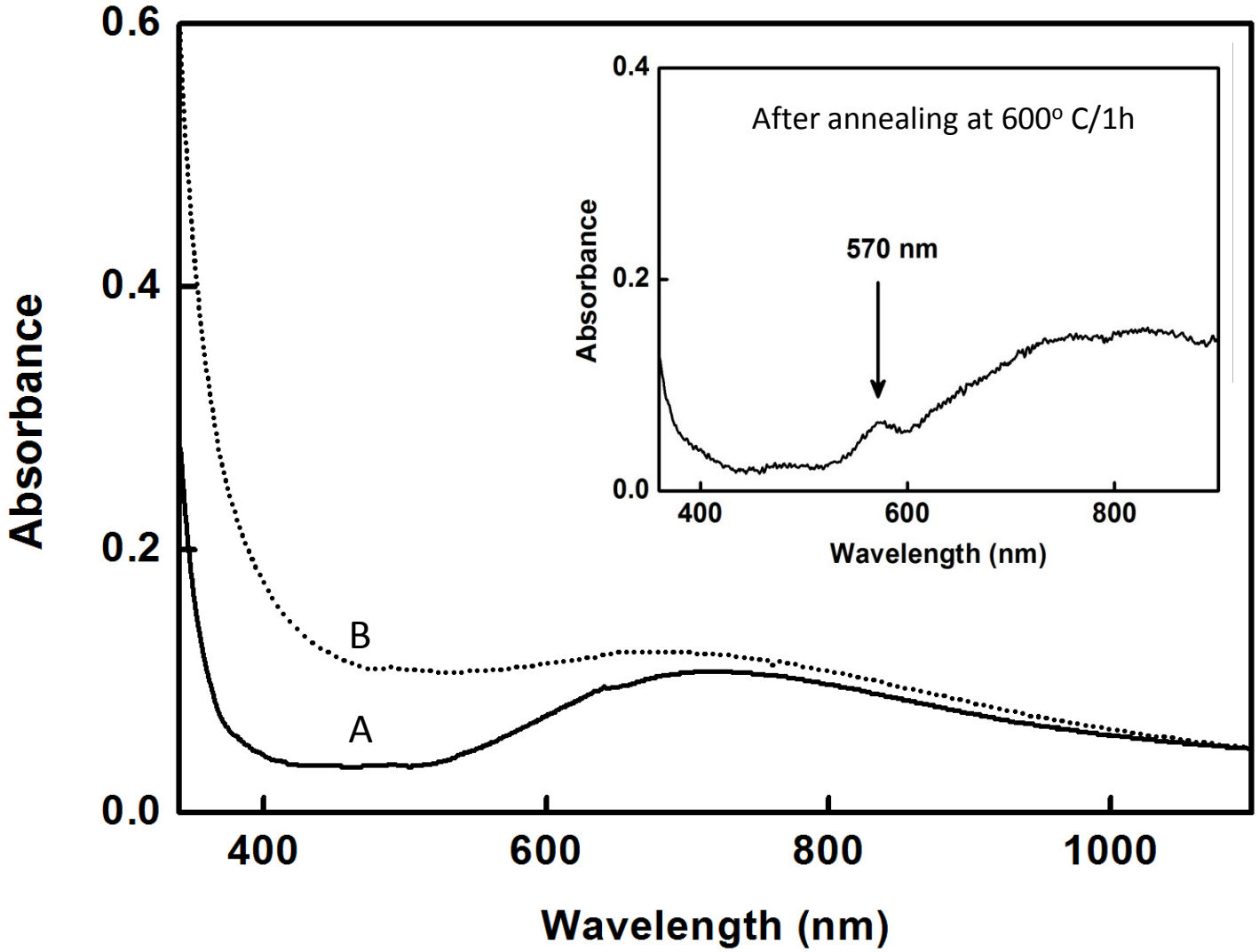
Methodology

Fs-laser irradiation and subsequent annealing

Micromachining set up

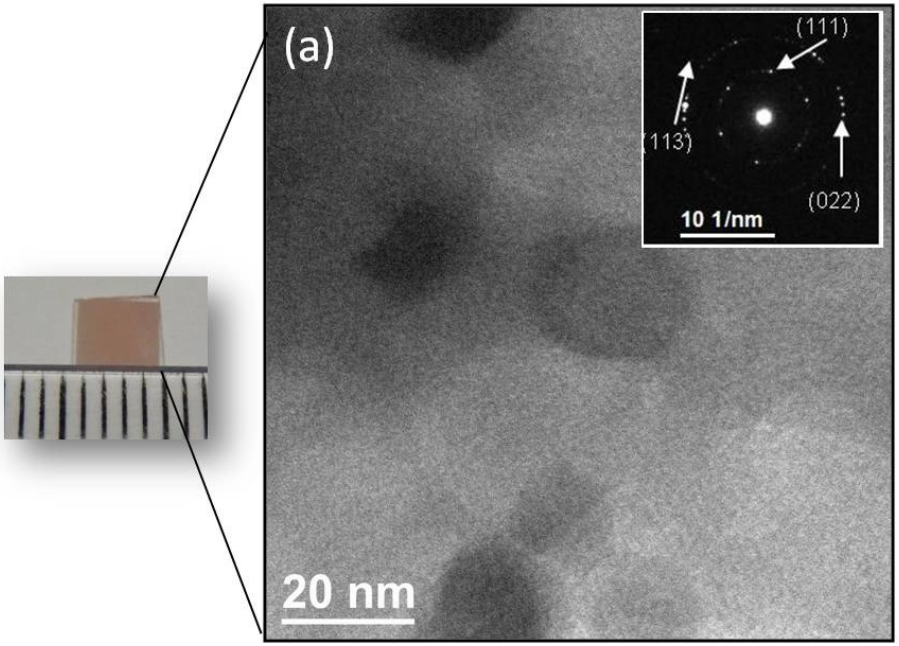


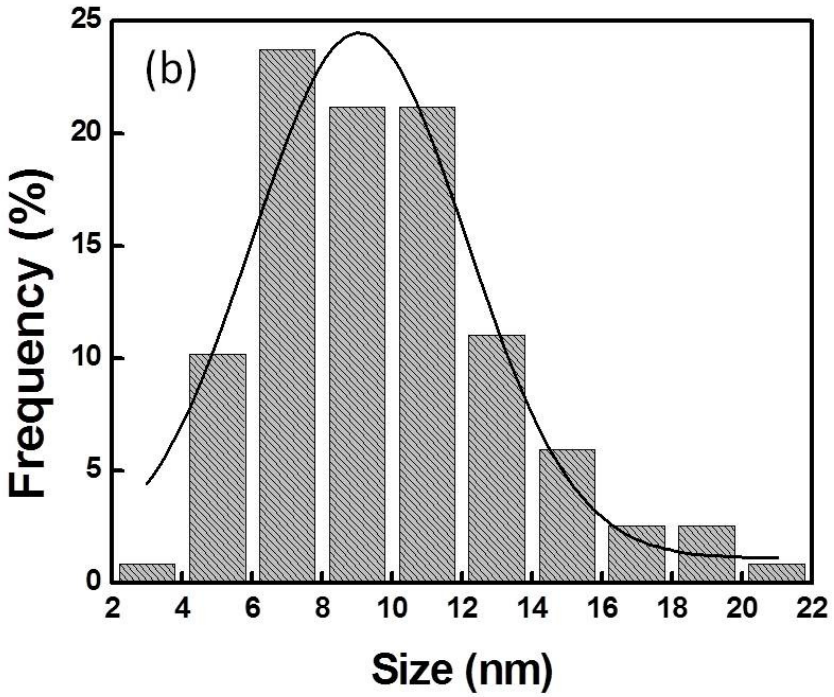
Results



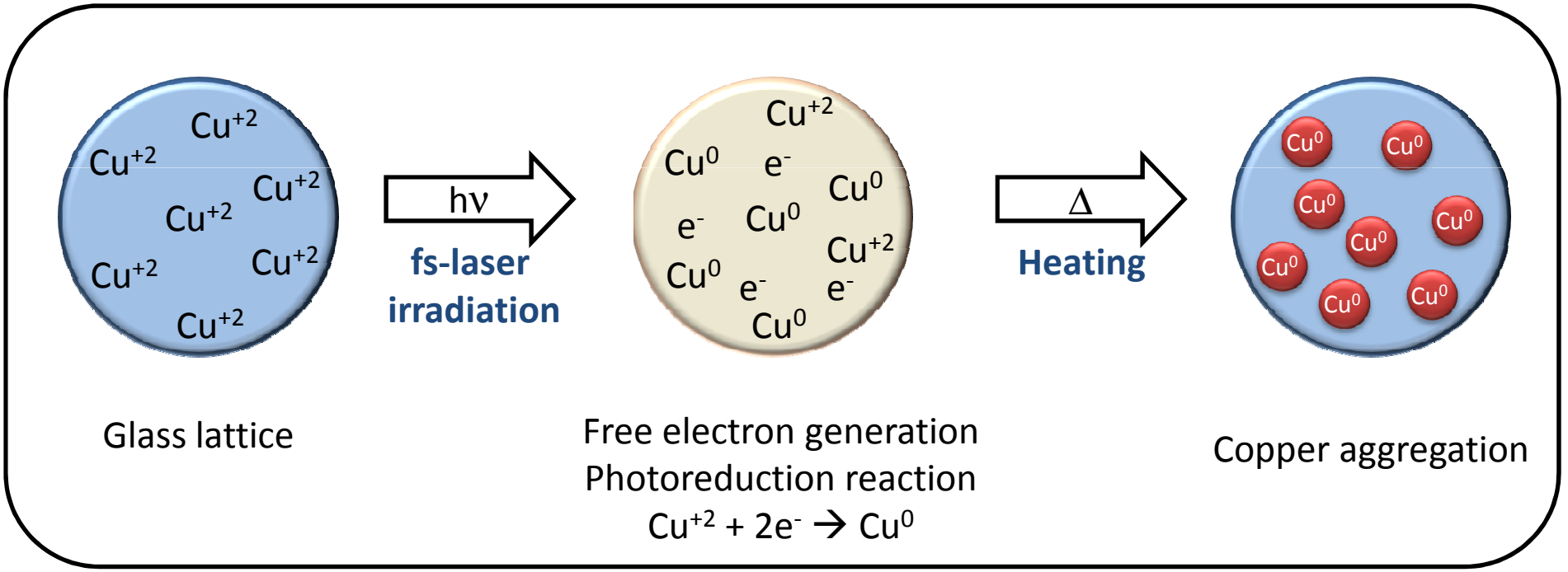
Absorption spectrum of the copper doped borosilicate glass as prepared (curve A), and after the fs-laser irradiation in the bulk using NA = 0.65, v = 100 µm/s, E = 92 µJ (curve B).

Transmission electron microscopy and electron diffraction





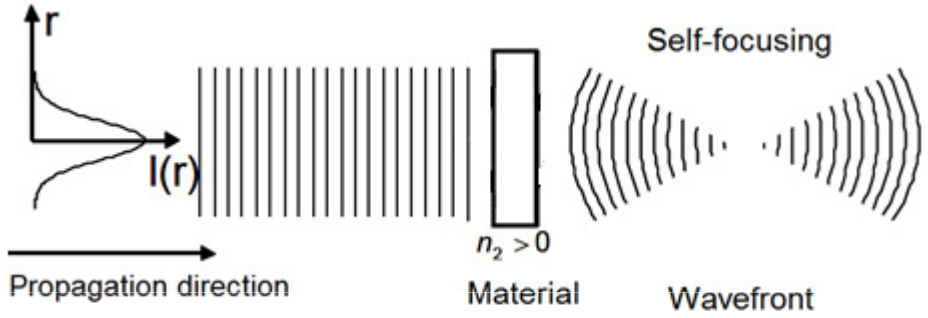
Metallic nanoparticles formation

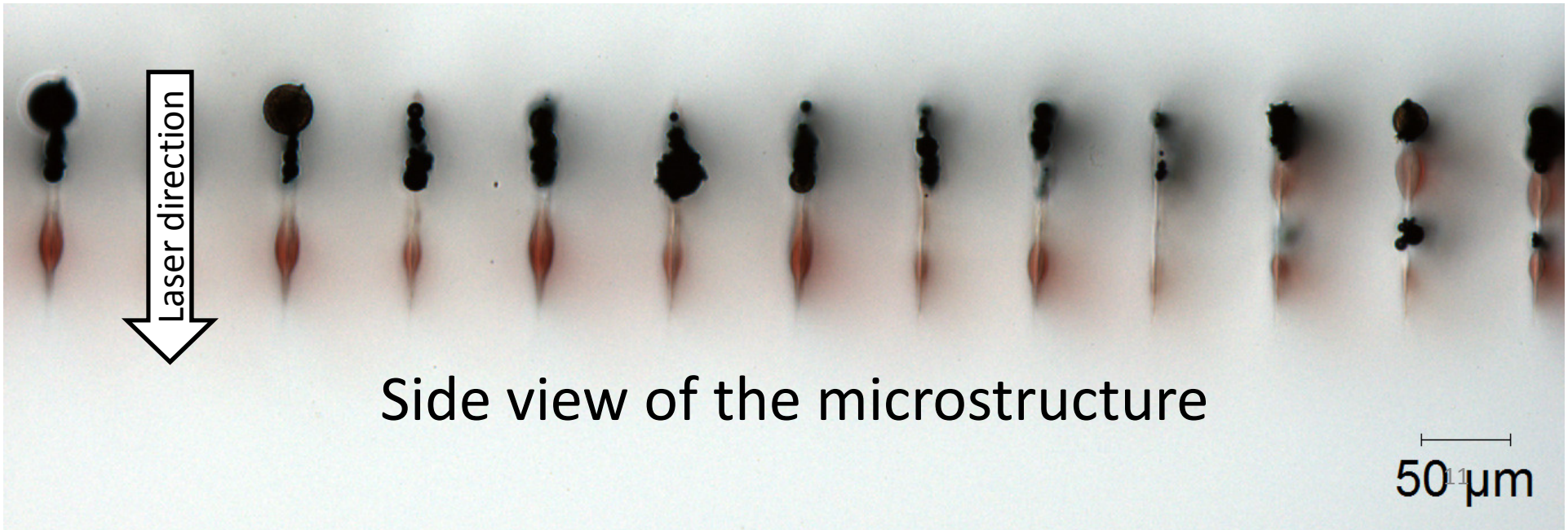


Self-focusing effect

It is a consequence of the intensity-dependent refractive index - Kerr optical effect, $n = n_0 + n_2 I$

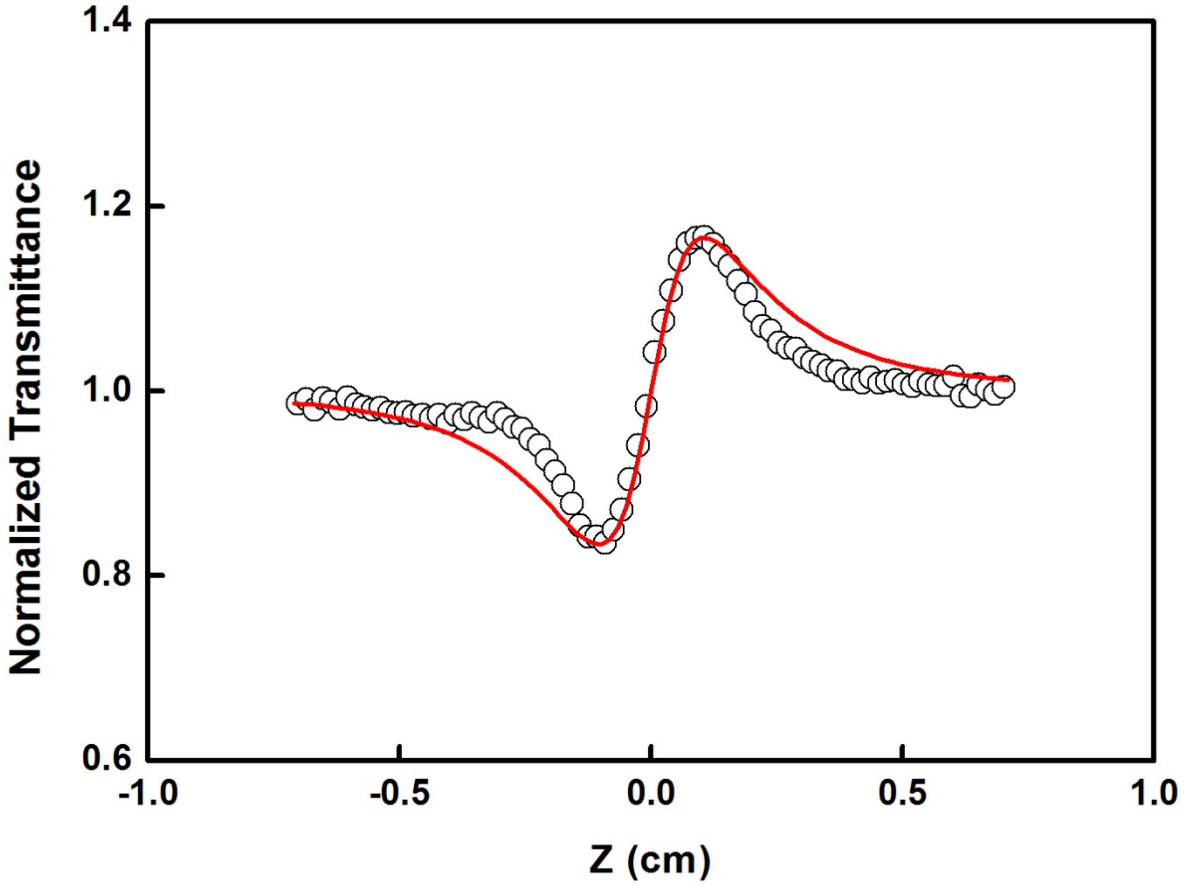
Self-focusing occurs when a nonuniform intensity distribution propagates through a material with positive nonlinear refractive index.





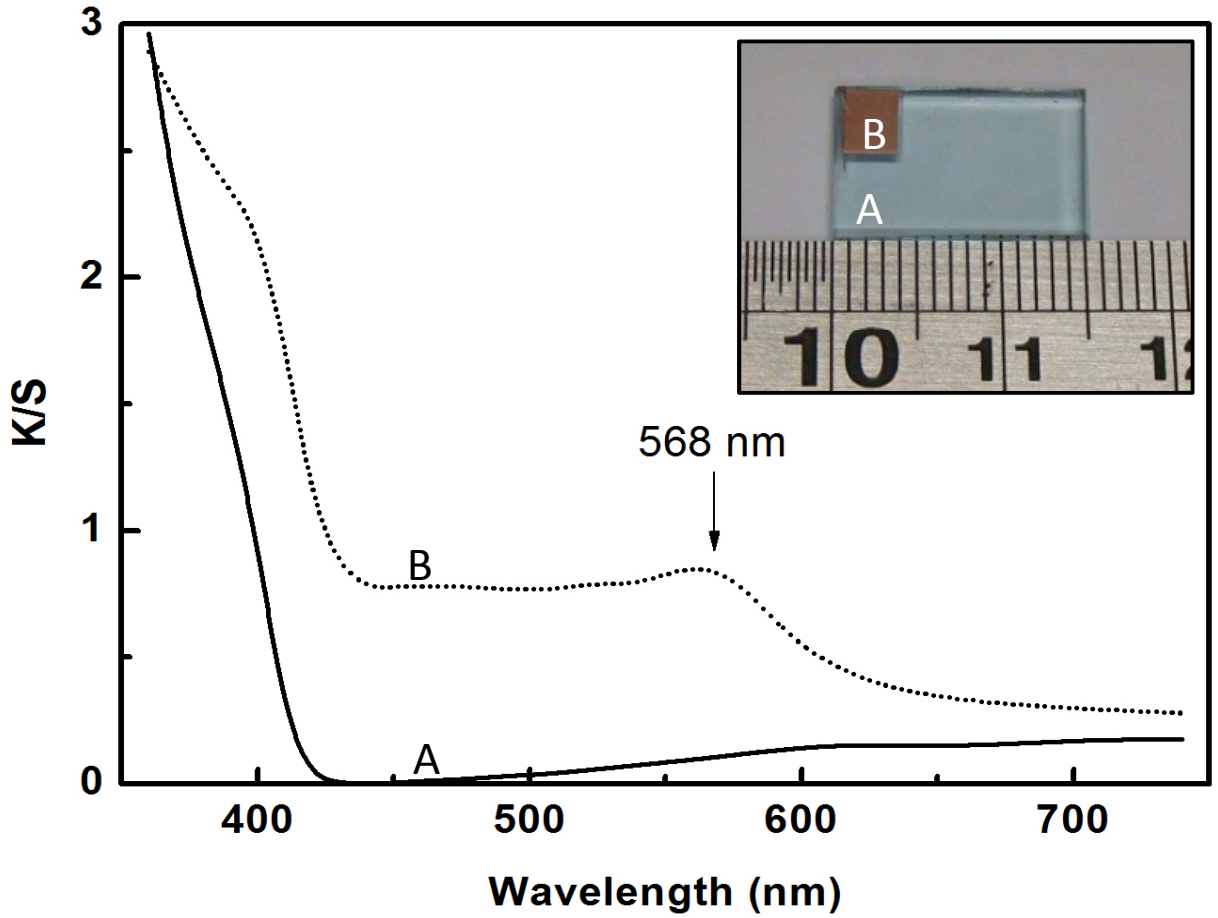
Optical Kerr effect

$n = n_0 + n_2 I$ $\quad n_2 = 3.10^{-20}\ m^2/W$ at 775 nm



Closed aperture Z-scan signature

Copper nanoparticles on glass surface

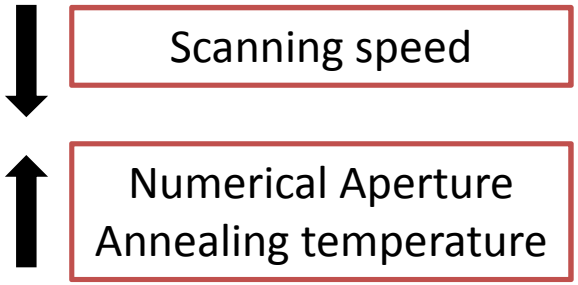


Absorption and scattering coefficient (K/S) spectra obtained from diffuse reflectance, of the sample as prepared (curve A), and after irradiation (NA = 0.25, E = 258 μJ, v = 1000 μm/s) and further annealing at 570° C/1h (curve B)

The influence of the experimental parameters

Irradiation position	Microscope objective	Laser scanning speed (µm/s)	Annealing (°C)	Surface Plasmon Resonance band
Surface	NA = 0.25	1000	570	Yes 
Bulk	NA = 0.25	1000	570	No
Bulk	NA = 0.65	100	600	Yes 

We have suggest that there is an optimal combination among the experimental parameters so that the grown of the nanoparticles may happen.



Conclusions

- We have shown the formation of copper nanoparticles in the bulk and on the surface of the copper doped borosilicate glass by femtosecond laser irradiation and further annealing.

- The size of the nanoparticles is around 9 nm, and they are composed by metallic copper atoms.

- Slower scan speed, higher intensity of the laser beam and higher heating temperature favors the nanoparticle formation process.

- A preferential accumulation of the nanoparticles in the bottom region of the microstructure was observed due to a self-focusing effect.

Acknowledgements

For a copy of this presentation

www.photonics.ifsc.usp.br

Presentations


IFSC OSA Student Chapter Apresenta:
EAOF
IV Escola Avançada de Óptica e Fotônica
16 a 19 de Julho de 2012
Anfiteatro Horácio Panepucci - IFSC - USP São Carlos
Oscar Martinez Universidade de Buenos Aires
Phototermal microscopy and related techniques for materials characterization
Donna Strickland University of Waterloo
High-intensity laser systems for nonlinear optics
Robert Wolf Newport
Recent Advances in Commercial Ultrashort Pulse Laser Systems
Osvaldo Novais de Oliveira Júnior FAPESP
Science and technology in São Paulo, Brasil
Carla C. Schimit IQSC – USP
Interações entre a luz visível, corantes e compósitos de polímero-argila: fotopolimerização e fotodegradação
Isabel C. S. Carvalho PUC-RIO
Nanopartículas e nanobastões de ouro em fibras ópticas para sensoriamento
Philippe Courteille IFSC – USP
Como a luz interage com nuvens atômicas
Sandro Marcio Lima UEMS
Materiais fotônicos para geração de luz branca sintonizável
Daniel S. Corrêa EMBRAPA - Instrumentação
Microfabricação de estruturas poliméricas utilizando laser
Denise Zezell IPEN
A fotônica no desenvolvimento de métodos diagnósticos e terapêuticos: experiência do IPEN
Apoio
OSA Optical Society of America
CNPq
USP Pró-Reitoria de Pesquisa
IFSC
Lynx Comércio e Importação Ltda
EPTV
Inscrições no site: www.osa.ifsc.usp.br/eaof4 - De 01/05 a 11/06