Nanocluster production by pulsed laser ablation in liquids

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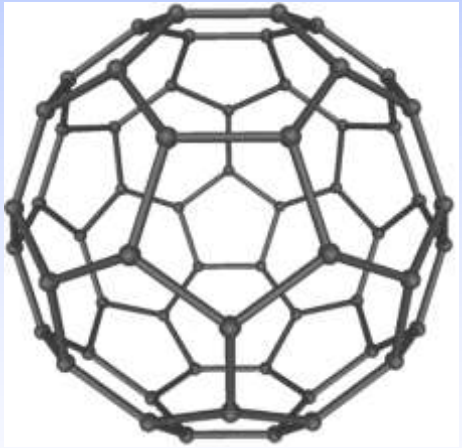
Atomic nanocluster

- Consist of 2 – 10^3 atoms
- Size 1 ÷ 100 Å
- Molecular behavior
- Additional atom changes both geometric and electronic structure
- Cluster stability is variable
  - Electronic structure
  - Number of atoms
  - Size
  - Isomerism
  - Stoichiometry



Atomic nanoclusters

- Applications:
  - Catalysis
  - Biolabeling
  - Surface-enhanced Raman scattering
  - Metal-enhanced fluorescence
- Production methods:
  - Chemical reactions
  - Condensation on a substrate
  - Irradiation of a solid
  - Laser Ablation (LA)

$(CdSe)_{33}$. $(CdSe)_{34}$

Ag (0,5 – 17 nm) with Qy =0.09

1. Kasuya A, et al. Ultra-stable nanoparticles of CdSe revealed from mass spectrometry. *Nature materials*. 2004
2. Park YS, Dmytruk AM, Dmitruk IM, et al. *The Journal of Physical Chemistry C*. 2010
3. Kravets VV, Culhane K, Dmitruk IM, Pinchuk AO. *Proceedings of SPIE*.Vol 8232.; 2012

Laser ablation

- Laser Ablation is removal of the material because of the incident light
- Temperature 3000-10000 K
- Pressure at ablation point 100-1000 bars

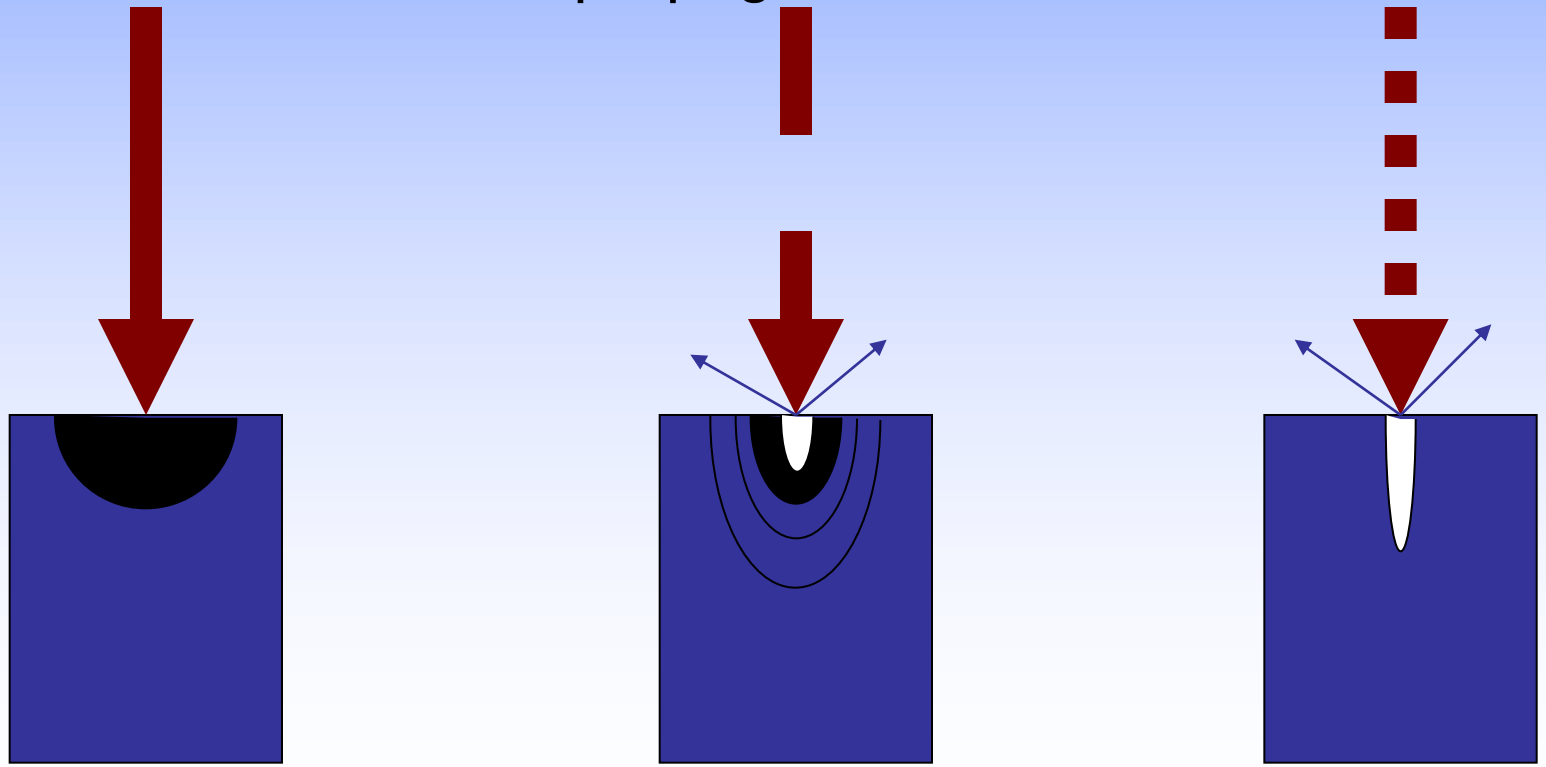
http://www.strath.ac.uk/space/research/missionsystems/asteroiddeflectiontechnologies/laserablationexperiments/

Pulsed laser ablation

CW/microsecond
- Boiling

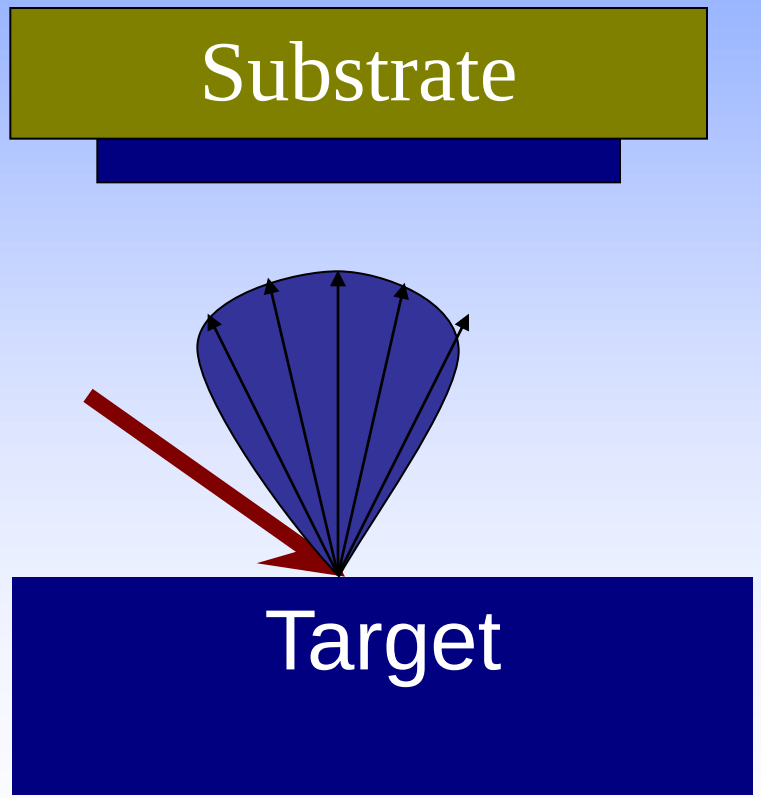
Nanosecond
- Vaporization
- Shock wave propagation

Pico-, Femtosecond
- Vaporization
- Ionization
- Nonlinear absorption

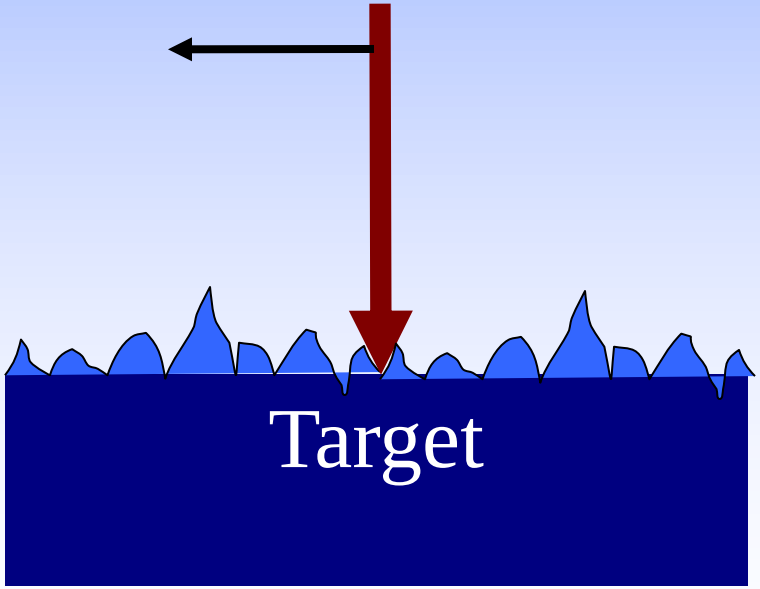


Pulsed laser ablation

Film deposition

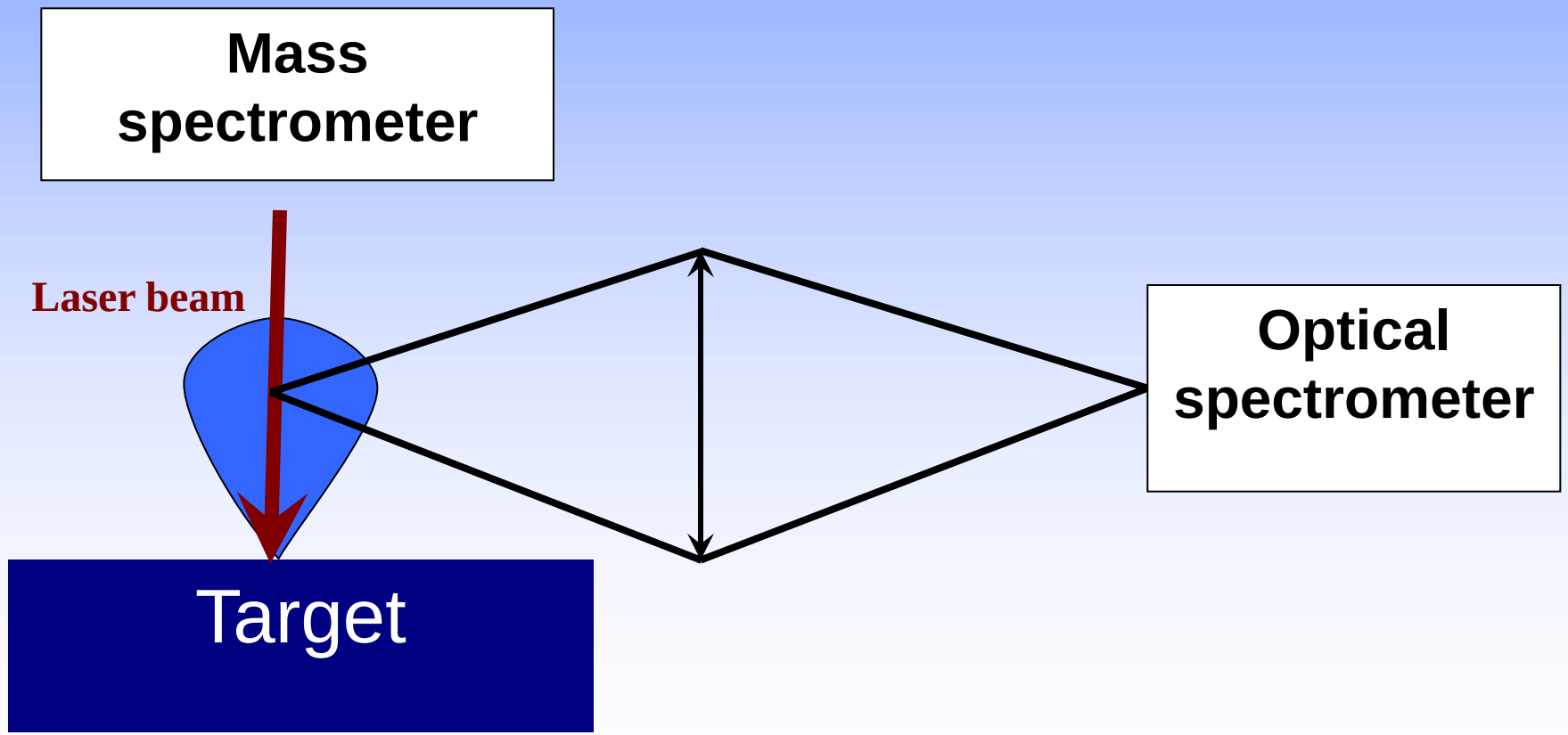


Surface cleaning

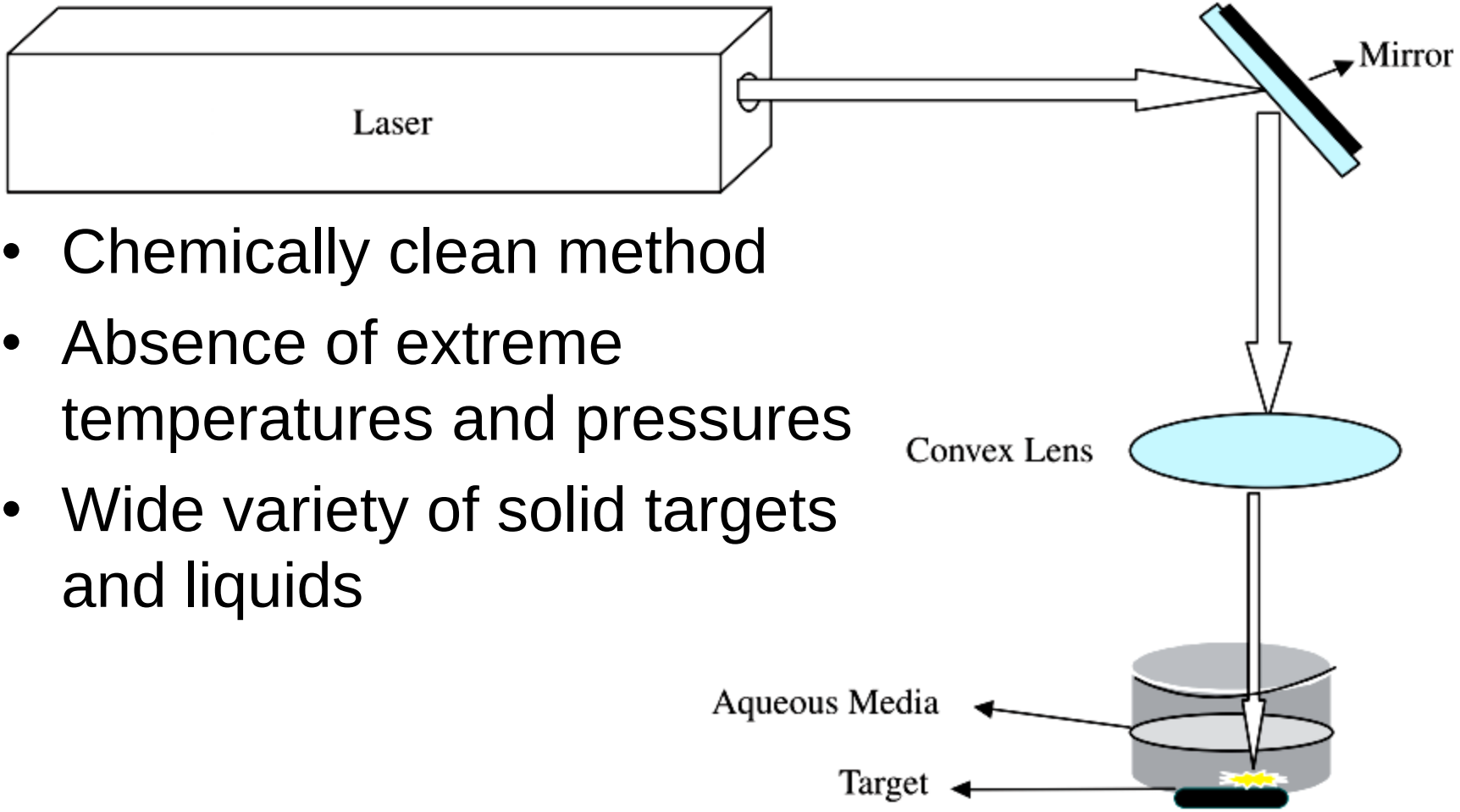


Pulsed laser ablation

- Material characterization



PLA in liquids to produce nanocluster

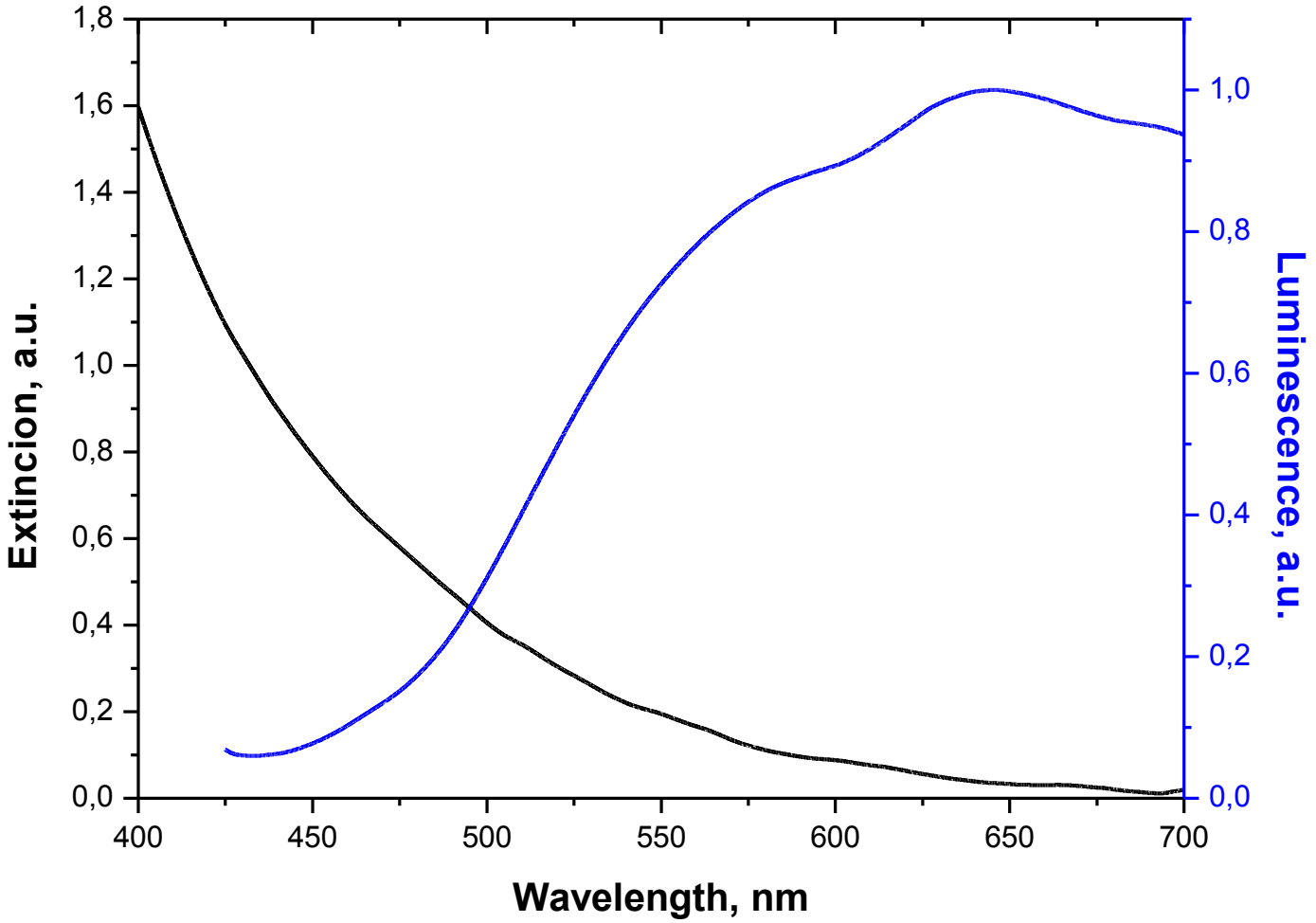


- Chemically clean method
- Absence of extreme temperatures and pressures
- Wide variety of solid targets and liquids

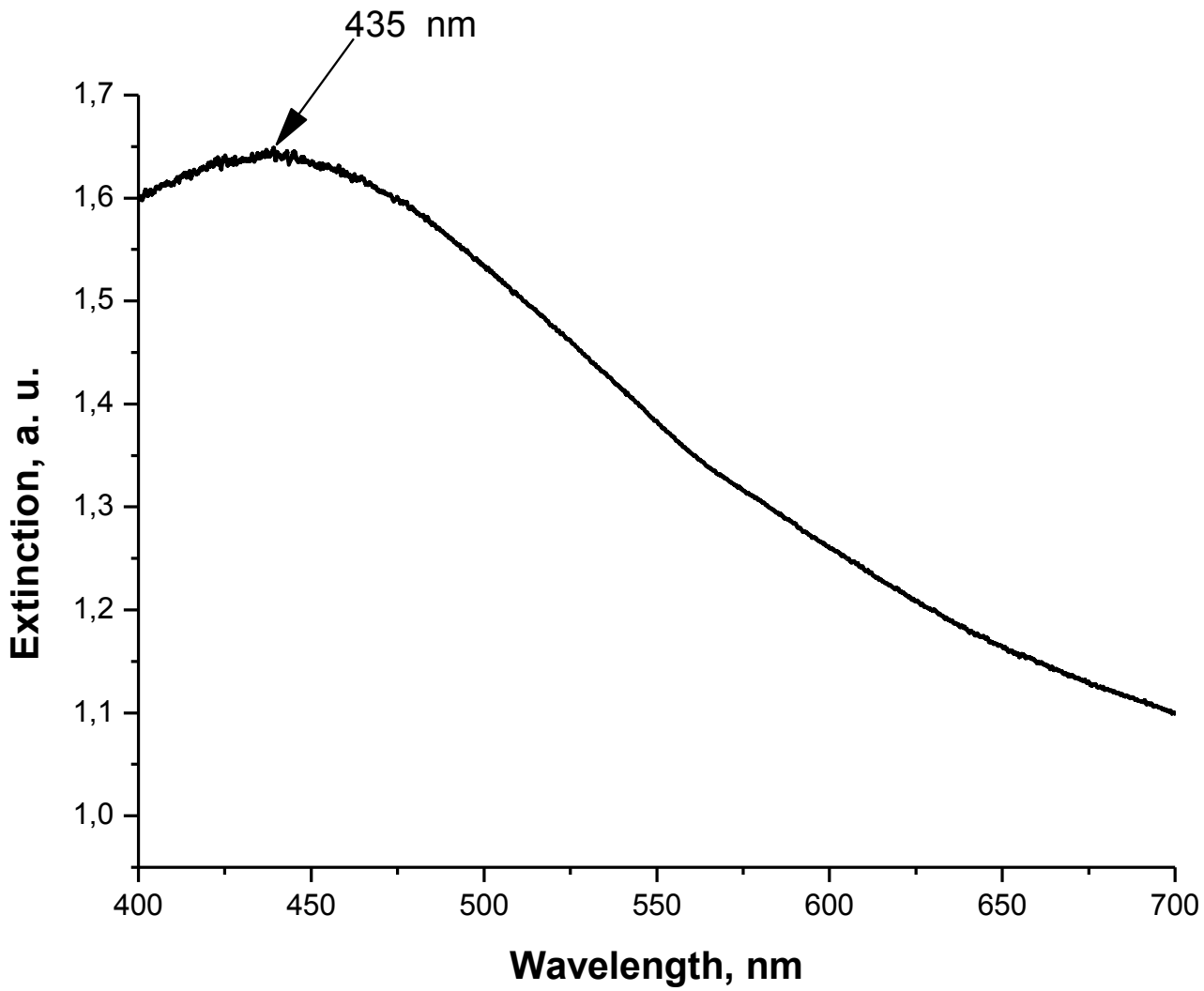
S. C. SINGH and R. Gopal,, vol. 40, no. 4, pp. 724–730, 2008.

Results: Cd-Se

CdSe nanoparticles in water were stabilized by L-cystein, (pH 10)



Results: Ag in water



Future perspectives and tasks

- PLA in liquids has great potential due to liquid and material variety
- In order to achieve smaller particles' sizes and dispersion, laser pulses parameters should be optimized

- Our main future task is to obtain "magic sized" clusters

Conclusions

- Nanoclusters were successfully produced by pulsed laser ablation
- Wide absorption peak is an evidence of nanoparticles formation with various sizes both of Ag and CdSe
- Luminescence and absorption spectra investigations should be extended to UV region

THANK YOU FOR ATTENTION

Acknowledgements
Ivan Blonskii
Andrij Dmytruk

Femtosecond laser complex

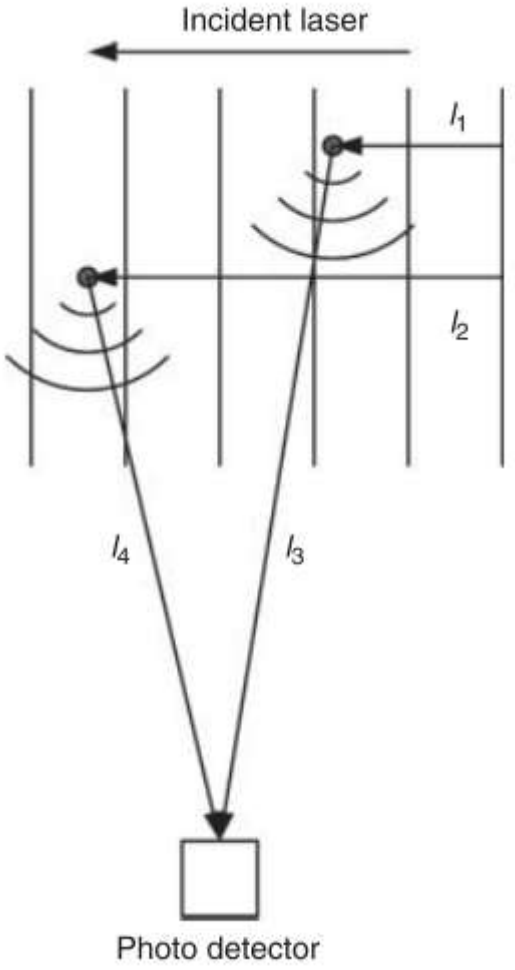
- Main parameters
  - Wavelength 800 nm;
  - Pulse duration 130 fs;
  - Maximum pulse energy 2,5 mJ;
  - Maximum peak power $2*10^{10}$ W;
  - Maximum power density 5×10^{14} W/cm^2;

Dynamic light scattering

- Laser irradiates suspension of nanoparticles
- Brownian motion causes fluctuation of scattered light intensity
- The characteristic time* of this fluctuation is related to diffusion coefficient

$$\tau = (2Dk_s)^{-1} \qquad D = KT / 6\pi\eta R$$

* Autocorrelation function is used to determine characteristic time



Yin, L. (2012), Wiley-Blackwell, Oxford, UK. doi: 10.1002/9781118229347.ch8