OPTICAL BISTABILITY AND HYSTERESIS IN THE SYSTEM OF LASER DIODE WITH ABSORBING NANOSUSPENSION

G. Pobegalov1, P. Agruzov2, I. Ilichev2, A. Shamray2

1St. Petersburg State Polytechnical University, St. Petersburg, Russia
2Ioffe Physical-Technical Institute of the Russian Academy of Sciences, St. Petersburg, Russia

Since its first discovery in late 1970’s, optical bistability has been found existing in many different optical systems and has received much attention with optical computing and all-optical switching considered to be potential applications. Generally, bistable optical systems containing either a saturable absorbing or a nonlinear dispersive medium. The use of aerosols and suspensions of dielectric nanoparticles (so called “soft matter”) as nonlinear optical media is quite attractive since nonlinear effects can be observed at very low power level. In addition, same process will in turn affect the nonlinear medium, thus leading to a mutual interaction between the light and the nanoparticle system and potentially allows controlling nanosuspension properties at the mesoscopic level. It makes such system of a great interest for the booming area of optofluidics.

In this paper we report the investigation of the optical bistability and hysteresis in the system comprising the semiconductor laser diode working near threshold at the wavelength 980 nm and colloidal solution of LaF3: Er,Yb nanocrystals having a resonance optical absorption at the same wavelength 980 nm.

![Fig.1. Experimental observation of optical bistability: (a) – experimental setup, (b) – experimental dependence of the beam cross section intensity distribution versus input optical power.](image)

The scheme of the experimental setup is shown on the Fig. 1a. The input beam at 980 nm from fiber pigtailed semiconductor laser was formed by standard FC collimator and illuminated a cuvette with nonlinear nanosuspension. LaF3: Er,Yb core-shell nanocrystals, stabilized with oleic acid ligand, were prepared by the coprecipitation technique in aqueous/ethanol solution. We chose 20% (molar ratio) Yb3+ ions as co-doping concentration in the preparation of the nanocrystals. The obtained nanocrystals was redistributed in toluene which was used as the solvent based on following two factors: (1) it does not exhibit absorption bands in NIR region because of low fundamental vibration energy and (2) it has a relatively high refractive index compared with other solvents and therefore minimizes loss of light due to Rayleigh scattering. Obtained nanosuspension had high optical nonlinearity related to the thermal lensing and light induced Soret effects. An effective nonlinear coefficient \( n_2 \) estimated from Z-scan experiments was about \( 1.2 \times 10^{-12} \) m²/W. The optical feedback was provided by a mirror which directed the light beam back to the fiber pigtail to be a spatial filter simultaneously. For the laser diode working near threshold the optical feedback reduces the population inversion and decreases output power. The coefficient of the optical feedback depends on a beam distortion in the nonlinear medium which in turn is defined by light intensity or laser output power, thus the conditions for bistability were arose.

Typical hysteresis loop is shown on the Fig 1b. Note that rather low optical power (in the range of a few milliwatts) is required for switching. The influence of the solution concentration, external mirror reflectivity, as well as temporal dynamic of switching have been thoroughly investigated.

In conclusion, we have shown that colloidal solutions of absorbing nanoparticles exhibit high optical nonlinearity. For the first time an optical bistability and hysteresis were observed in the system of laser diode with external optical feedback comprising colloidal solution of LaF3: Er,Yb nanocrystals. A new type of soft matter is very promising as nonlinear active material in laser applications and for optical manipulation in microfluidic devices.