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Energy Structure and Strong Optical Nonlinearities of Porous Si

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The bleaching bands (Fig.1) corresponding to the transitions between the levels of size quantization were observed in the nonlinear transmission spectra of porous crystalline Si wires (quantum wires) while the linear absorption spectra had no perculiarities dealt with space confinement probably because of strong inhomogeneous broadening caused by size dispersion of wires.

The layers (20-50μm) of thin silicon wires were prepared by electrochemical etching of n-type (111) wafers and then splitted from the wafer by applying a short pulse of electrical current (100 mA/cm^2).They were excited by picosecond pulses of the second harmonic of Nd:YAG laser and probed by the pulse of picosecond continuum.

The induced decrease of absorption was explained by filling of the size-quantized energy levels with nonequilibrium carriers (saturation effect). Instead of the indirect gap of crystalline bulk silicon,the band structure of the wires exhibits a direct gap - the projections of four valey minima of bulk silicon oriented along (100) and (010) directions onto the wire axis are at the zone center / 1 /.The energies of two bleaching bands correspond to that of size-quantized wire with about 3x3 nm^2 cross section (the lowest transitions E_{11}^h,E_{11}^l for electrons with effective mass in (110) and ($\bar{1}$10) confinement directions and heavy and light holes).Probably only part of the wires with proper cross section (proper energy spectra) were resonantly excited by the laser beam.Similar effect of inhomogeneous broadening suppression was observed in / 2 / for semiconductor nanocrystals (quantum dots) with considerable size dispersion.

The E_{11}^l-band could be seen only at zero delay of the probe pulse; the relaxation time of E_{11}^h-band for porous Si (300 K) was about 40 ps.

The values ($\sim 10^{-8}$ esu) and dispersion of imaginary part of third order nonlinear susceptibility $\chi^{(3)}$ were obtained.

The possibilities of application of the observed strong and fast nonlinearities $\chi^{(3)}$ in Si quantum wires for fast optical switching and the probable channels of luminescence (Fig.2) and stimulated emission will be discussed.

1.G.D.Sanders and Yia-Chung Chang,Phys.Rev.B,45,9202,(1992)
2.V.Dneprovskii,V.Klimov,D.Okorokov,Yu.Vandishev,Solid State Communications,81,227,(1992)

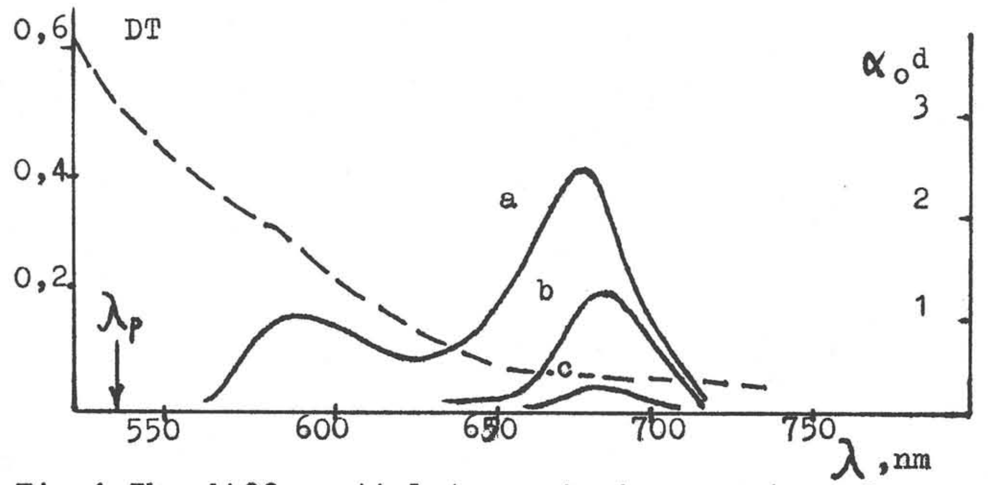

Fig.1.The differential transmission spectra of porous Si at different delays after excitation: t=0 (a),30 ps (b), 90 ps (c),and the linear absorption spectrum (dashed line)

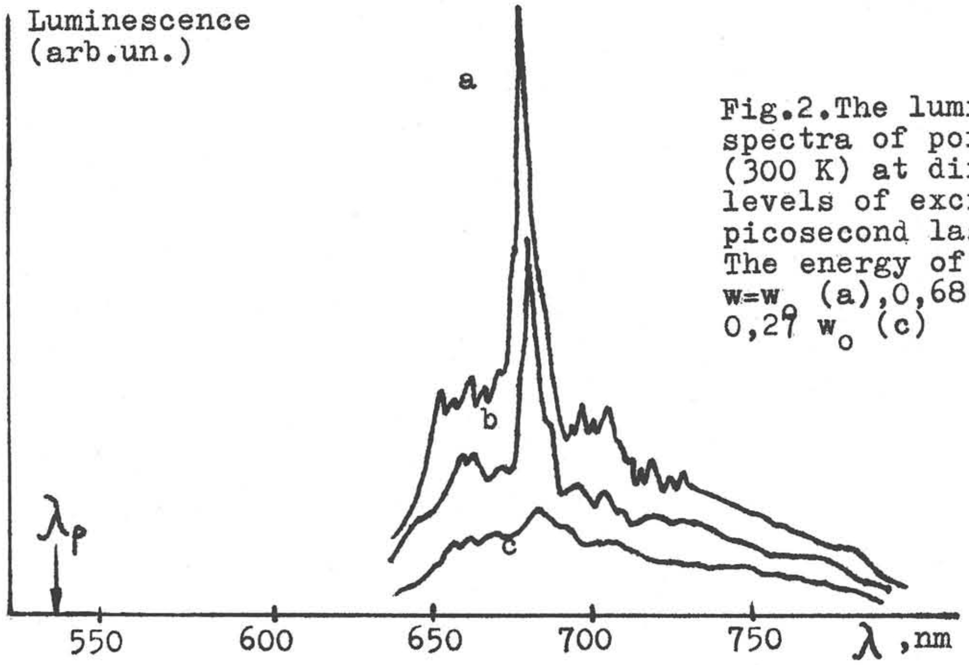

Fig.2.The luminescence spectra of porous Si (300 K) at different levels of excitation by picosecond laser pulses. The energy of the pulse $w=w_0$ (a),0,68 w_0 (b), 0,27 w_0 (c)