Acoustic Metamaterials – New Materials for Acoustic Electronics

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Abstract - **Experimental results of the investigations of the photon-phonon interaction in orderly packed silica dioxide (opal matrices) and nanocomposites on their base are presented.**

Keywords - **Photon-phonon interaction, Opal matrices, Acoustic vibrations of nanospheres.**

INTRODUCTION

Theoretical and experimental investigations were initiated last years on metamaterials synthesis and study, named as photonic crystals [1, 2]. Indeed, as known, irrespective of wave nature group velocity does not concur with wave vector direction without fail. It also relates and to acoustic vibrations in metamaterials, where state function behavior for various bands in photonic materials (including allowed and forbidden phonon bands) is defined by the peculiarities of group velocity in definite frequency range that is specified by metamaterial structure. Under certain conditions the states can appear with negative value of the corresponding coefficients and with forming the mode of total internal reflection in system for acoustic waves in definite frequency range.

EXPERIMENTAL

Ruby laser giant pulses (wave length of generation λ = 694,3 nm, laser pulse duration τ = 20 ns, maximal pulse energy E_{max} = 0,3 J) were used as the source of excitation. Exciting light has been focused into the material by lenses with different focal lengths (50, 90 and 150 mm). The sample distance from focusing system and exciting light energy were also changed. The optical scheme of the experimental setup for spectral characteristics of the scattered light measurement is shown at Fig. 1. We can observe a pattern of rings, width of which characterizes a spectral width of the initial light. For our laser it was equal to 0,015 cm^{-1}.

Linear function of photonic band D position and frequency shift of stimulated scattering relative to frequency of exciting radiation and D^{-3}, where D – sphere diameter is experimentally observed.

Measurements for functional plot of frequency shift and scattered radiation relative to laser radiation frequency and sphere diameter (Table).

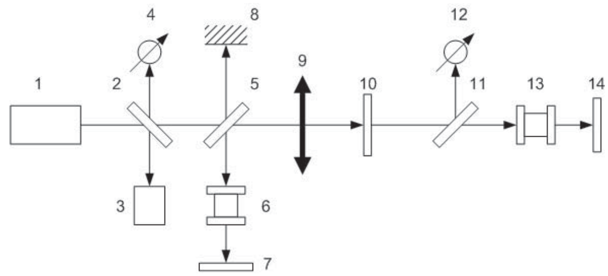

Fig. 1. Optical experiment scheme: 1 - ruby laser; 2, 5, 11 - glass plates; 3 - system for laser parameters control; 4, 12 - system for measuring the scattered light energy in backward and forward directions; 6, 13 - Fabri-Perot interferometers ; 7, 14 - systems of spectra registration; 8 - mirror; 9 - lens; 10 - sample

TABLE

ν_i, GHz Experimental value	Nanosphere diameter *D*, nm, ±5 nm. (electron microscopy data)	$(\nu_0/\nu_i)^{1/3}$	Nanosphere size, nm. (Calculated under cubic function)
5,1	315	1,297	317,7
6,6	290	1,189	291,3
7,8	270	1,125	275,6
ν_0 = 11,1	245	1,0	245
12,1	240	0,94	231

CONCLUSION

The considered effects can occur in photonic-phonon metamaterials as opal matrices under condition of definite vibration mode due to interactions between photonic and phonon subsystems (as described in case under consideration)

Financial support from RFFI (Grant № 08-02-13500-ofi_c; 09-02-13531-ofi_c) is acknowledged.

REFERENCES

[1] Lee Fok, Muralidhar Ambati, Xiang Zhang, "Acoustic Metamaterials," *MRS Bulletin*. 2008, vol. 33, pp. 931.

[2] Nanomaterials. III. Photonic crystals and nanocomposites based on opal matrices, Ed. M. I. Samoylovich. M.: CRTI "TECHNOMASH". 2007. 303 p.