Focusing the acoustic emission by the crystal with nonlinear interaction

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Abstract

In this paper we describe experimentally observed radiation focusing of piezoelectric element placed in the center of the phonic crystal in the focal spot outside of the crystal with dimensions smaller than the wavelength (~ $\lambda / 3$) and with high contrast. We investigate the frequency dependence of the transmission coefficient as a permitted as prohibited the zones. Their maximum and minimum values differed up to 5 orders of magnitude. Observed non-linear parametric conversion of radiation due to the nonlinearity of the air excited by piezo vibration at frequencies lying inside the gap (as in a quantum dot). The intended use for the observed phenomenon further narrowing of the focal spot and enhance its intensity.

1. Introduction

A flat lens based on metamaterial with negative refractive index, proposed in 1967, V. G. Veselago [1] is of considerable interest both in research and in applied applications due to lack of distortion when transferring images from the object plane into an image. Implementation of the proposed metamaterial J. B. Pendry [2] and realized by D. R. Smith [3] not only experimentally proved the possibility of the existence of the phenomenon of negative refraction and allowed to ask about the possibility of obtaining subwavelength resolution using a flat lens metamaterial. Subsequent experiments have mainly focused on the observation of imaging a point source of light with subwavelength resolution in the focus of the lens plane in close proximity to the surface. To explain the effect of subwavelength resolution is usually involved in the submission of existing near to the surface of the evanescent modes are strongly damped with increasing distance from the surface of the metamaterial. Another method of forming a flat lens with similar properties is the use of photonic or phononic crystals [4], [5] with a negative dispersion characteristic and, respectively, with negative refraction. The latter case is the subject of a pilot study in our work. In addition, it is interesting the possibility of excitation of nonlinear vibrations in the air filling the phononic crystal in the forbidden zone.

2. Phononic crystal as focuser

Block diagram of the experimental setup is shown in **Fig. 1.**

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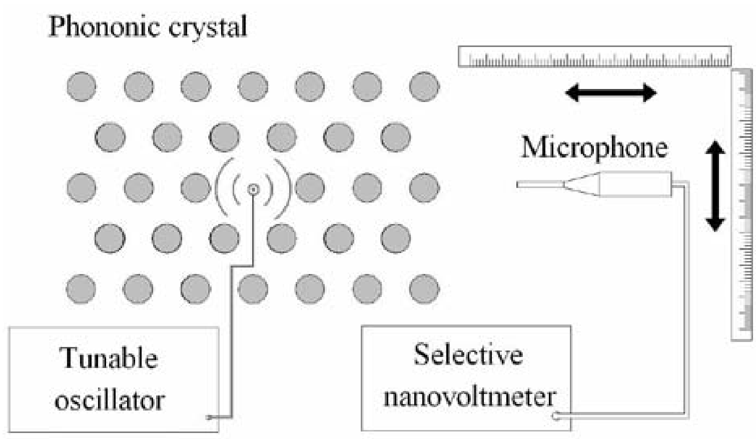

Fig. 1. Block diagram of the experimental setup

Phononic crystal similar to that described [6] in the form of a triangular lattice of steel cylinders with a diameter $d = 16$ mm and a length $l = 200$ mm in the air, had a lattice constant $a = 18.6$ mm and the filling factor of $s = d / a = 0.86$. Such a crystal has a negative dispersion characteristic and negative refractive index $n \sim -1$, and therefore can serve as aberration-free flat Veselago lens. In the center (without one element of structure) of the crystal size of the monopole located piezoelectric transducer. His image was recorded movable in three mutually perpendicular directions with a microphone, a receiving area with a diameter of 6 mm. The result of recording the minimum value of the focal spot is shown in Fig. 2.

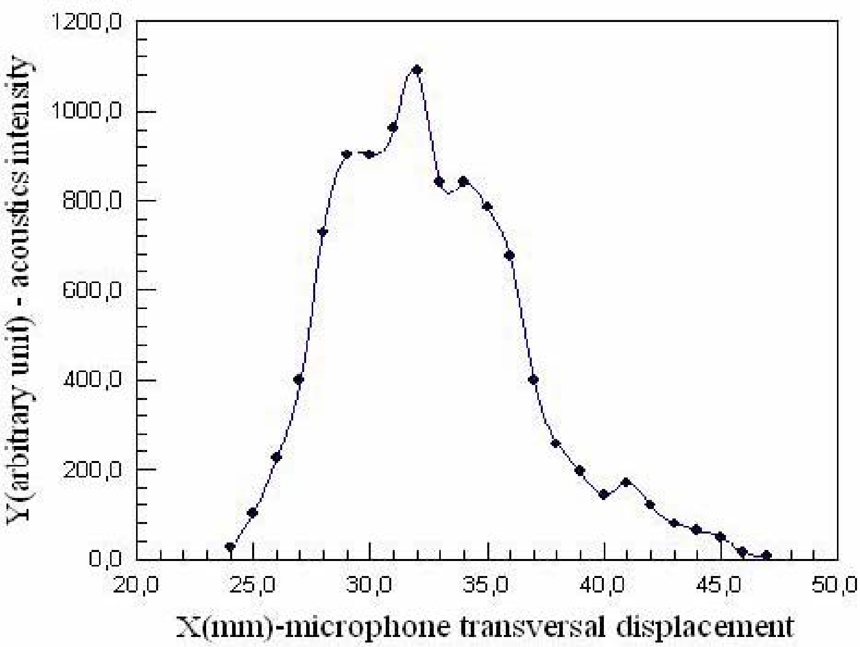

Fig. 2. Subwave resolution at $\lambda = 2.5$ cm

From these data it is obvious the presence of high-contrast spots with half-width less than the wavelength ($\sim \lambda / 3$).

3. Nonlinear Phenomena.

Of considerable interest to study the characteristics of the band with the above setup. The frequency dependence of the transmission coefficient (in power) on the frequency of sound is shown in **Fig. 3.**

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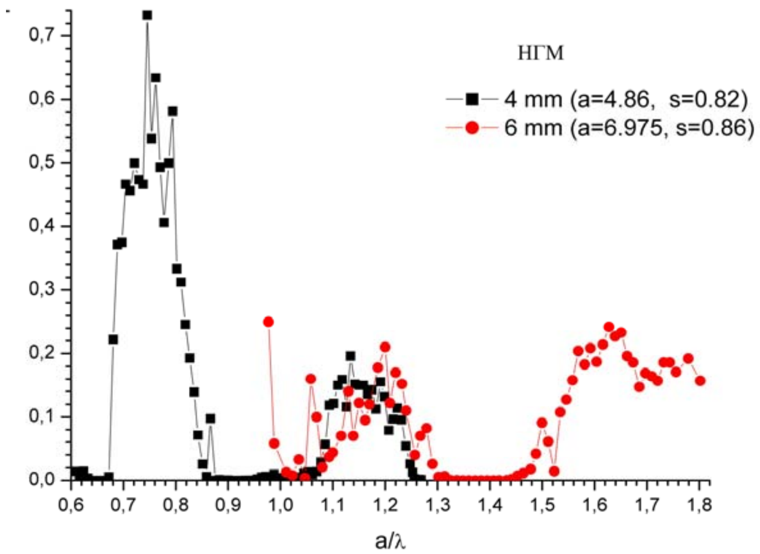

Fig. 3. Zones transmissions of the crystal in orientations HΓM

The transmission value drops to 5 orders of magnitude in the middle of the forbidden zones, compared with the maximum of transmission in allowed zones. Piezoelectric oscillating at a frequency corresponding to the band gap is analogous to the quantum dot in the ordinary crystal, its radiation falls off exponentially to the boundaries of the phononic crystal, and a strong back to the emitter reflection of acoustic radiation leads to a strong rise of the field in it centre. We have experimentally observed a slow increase during a few seconds of oscillations leads to destruction of the transducer with the effective supply voltage of 4 V and generator power does not exceed 50 mW. The amplitude of the oscillation was so large that we could register higher harmonics. We believe that it is possible by using nonlinear parametric interaction of two sound emitters operating at harmonically related frequencies, further narrow the focal spot.

4. Conclusions

The experimentally observed the excitation of nonlinear vibrations of air filling the 2D phononic crystal with a frequency lying in the region of its band gap, at low power supplied to the electrical oscillations placed in the centre of the piezoelectric element.

Offered the possibility of parametric amplification and possibly narrowing of the focal spot produced by a crystal with negative phonon dispersion.

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