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Charge density wave transition probed by interferometric dilatometry

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We report on new method of measuring sample length, based on interferometric measurements. Motivation for exploring this technique is to study the coupling between *charge density wave* (CDW) and underlying crystal lattice. Several papers report the dilatation measurements on CDW systems which can be related to CDW transition [1], CDW hysteresis [2], as well as low temperature glass transition [3]. Coupling with lattice is also evident from calorimetric measurements at glass transition temperature [4]. Our aim is to apply this method to other CDW systems as well as other systems with electronic superstructure.

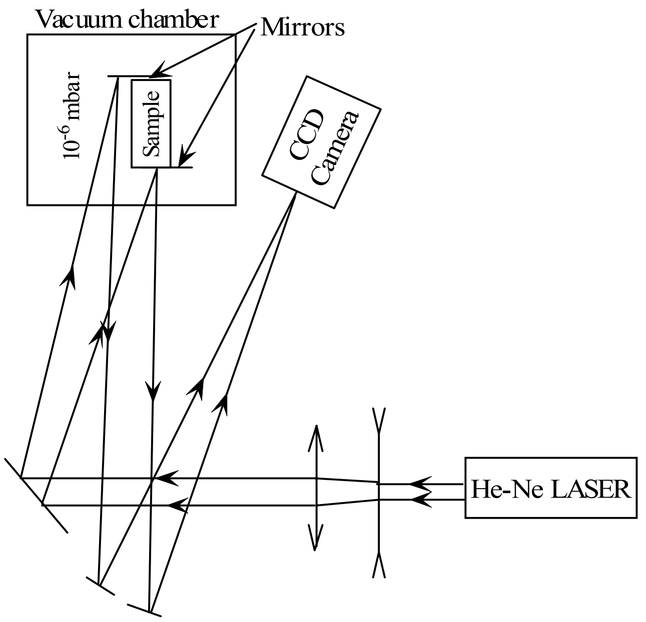

Figure 1. Principal scheme of optical setup used. Set of mirrors at the sample ends give two separate beams that interfere with each other, which has been recorded by a camera.

Setup of our experiment is schematically shown in Figure 1. He-Ne laser with wave length 632.8 nm and output power 25 mW, along with black-white 8-bit CCD camera with resolution 752x582 pixels have been used. Plain mirrors are used to direct light beams. Two mirrors at the sample ends reflect incoming beam creating two separate beams that are finally interfering in camera. Cooling has been performed using double-walled inox tube with copper block at the end. Inox tube was filled with liquid nitrogen, while the sample, thermometers, heater and lenses were mounted at the end of the copper block, which was inside the vacuum chamber. Recorded images show fringes that move through the picture as the length of the sample changes, Figure 2. Phase shift 2π of fringes in camera corresponds to change in sample length by half of laser wave length. Maximal theoretical resolution of such setup is:

Equation 1. $$\delta l = \frac{\lambda}{2}\frac{\delta\varphi}{2\pi} = \frac{\lambda}{2}\frac{1}{752\,pix} \approx 0.4\,nm,$$

though the noise (due to vibrations and defects of optical equipment) exceeded this value by far (~10 nm).

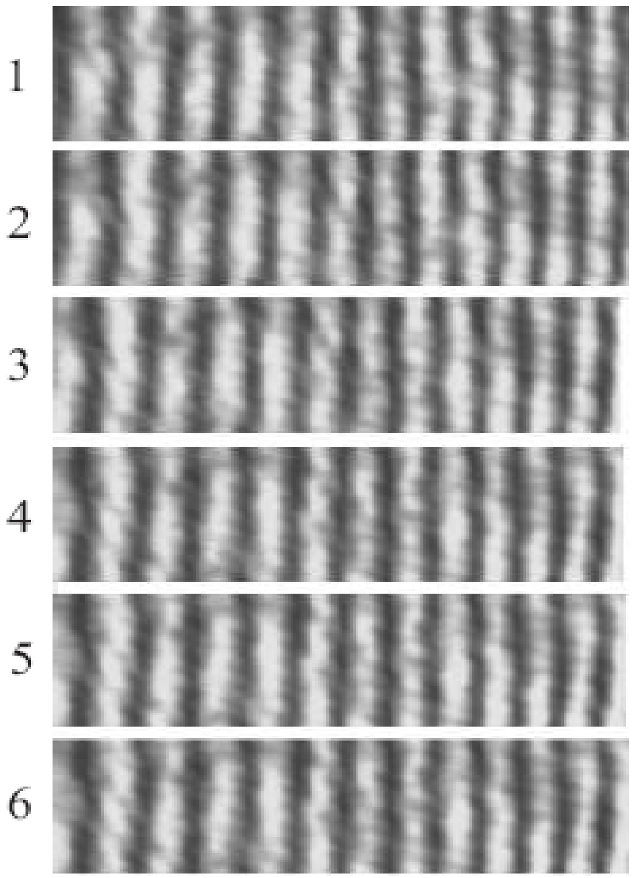

Figure 2. Consecutive interferometric samples which show shifting to the left side while the sample length is increasing.

In these, preliminary, measurements we studied dilatation in so-called telephone number compound $Sr_{14}Cu_{24}O_{41}$ [5]. This material undergoes transition to CDW state at 210 K. Measurements have been performed by increasing temperature from 205 K to 290 K. A change in expansion coefficient around phase transition has been observed, Figure 3. Expansion is slower while in CDW state.

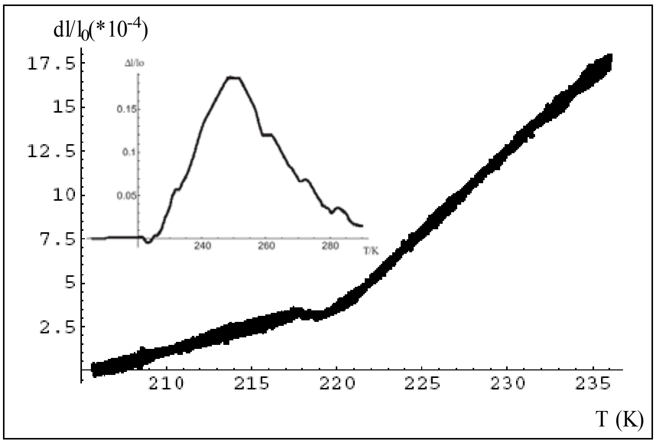

Figure 3. Relative dilatation of length vs. temperature.

Performed measurements are preliminary. We plan to measure temperature dependence of sample length with the same technique for number of other systems, like $(TaSe_4)_2I$, blue bronze, $(NbSe_4)_3I$, etc. Similar setup will be used for measuring changes of samples length in electric field and eventually the surface topology related to CDW domains. The advantage of this technique would be to provide non-contact information on static and dynamic changes in sample surface.

References

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