

## Digital Holographic Method for Piezoelectric Transformers Vibration Analysis

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**Abstract.** The paper describes a holographic method for vibration analysis in nanometer range. The method was successfully applied on different types of piezoelectric transformers and the measurement results are introduced. To proof the reliability of the method it was done a comparing simultaneous measurement of a piezoelectric component by the holographic method and the well-established single-point interferometric method. Results showing the minimal deviation of both methods are presented in the final part of the paper.

### 1 Introduction

A piezoelectric transformer (PT) is a device used for the transformation of alternating electric voltage by the means of ultrasonic vibrations. It utilizes converse piezoelectric effect in the input part and direct piezoelectric effect in the output part. The best transformation ratio is achieved at the mechanical vibration resonance. The measurement of out-of-plane displacement as well as the shapes of transformer vibration modes near resonant frequencies provides useful data, applicable in theoretical research of piezoelectric transformers behavior as well as in practical applications. A typical example is an effect of a transformer's properties as a function of its mechanical mounting.

PTs are used e.g. for Cold cathode fluorescent lamp electronics, high voltage generator for cold plasma, mobile phone battery recharging etc. High transformation ratio at no-load conditions is a specific feature of the PT's operation. PT applications are complex, including specific transformer mounting, wiring and driving circuit electronics. The out-of-plane displacement method is used for the PT vibration mode visualization. Studied PT's vibrate in planar modes. In-plane displacements must be re-calculated using finite element simulations.

On the market, there is a broad portfolio of measurement devices, which are usually based on

the Doppler phenomenon, correlation analysis, ESPI (Electronic Speckle Pattern Interferometry) and others. Another physical principle suited for vibration analysis is digital holography (DH) [1, 2]. The DH based methods are non-invasive, very precise and, in addition, DH enables displacement measurement over the whole-field.

The most common holographic method for vibration analysis is time average holographic interferometry, which was introduced by Powell and Stetson [3]. Unfortunately, for amplitudes smaller than approximately one tenth of the wavelength of the laser light used, the time-average method reaches its limit of minimum measurable amplitude. This problem was solved by frequency shifted holographic interferometry introduced by Aleksoff [4].

Typical analogue recording media, which was used in the past in holography, did not have uniform and repeatable response. Therefore it was impossible to determine quantitative values of amplitude precisely by the frequency shifted holographic interferometry method. The measurement usually served for estimation of vibration amplitudes and for mode structure determination.

In recent years, the resolution of CCD or CMOS have reached such a resolution, that it is possible to capture micro-interference pattern with high spatial resolution, which led to progress of DH. DH became









allowed measurement of the vibration of piezoelectric transformers in nanometer and sub-nanometer scale in the whole area. The measurement was done for resonant frequencies of ring and disc transformers driven by various voltage amplitudes. Moreover, the results of this developed method were compared to the measurement results of a single-point Michelson interferometer. It was demonstrated that this method is linear and reliable in the whole measurement range. The estimated measurement error of the method was estimated to 0.1nm.

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