Top and Back Plate Vibration Patterns and Frequency Response of Violin

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Introduction
The double pulse TV holography is a method of the vibration observation, that can depict diverse stages of the propagation of deformation after impact excitation, or, when the excitation is periodical, it can depict diverse phase of a deformation within period (T). Sound quality of musical instrument is determined by the amount of radiated energy of individual spectral components of its sound. When measuring a violin acoustic properties the Dünnwald's transducer [1] is often used to excite the bridge vibration instead of the string and the bow. Such substitution of musicians allows a long-term, stable and repeatable elicitation of investigated properties. Focusing on a vibration of violin, this type of the artificial excitation together with the use of the TV holography instrument Q-600 [2] allows studies of causal connections of the spectral components and the violin body deformations.

ESPI principle
The double pulse TV holography method (electronic speckle interferometer – ESPI) allows the non contact observations of the relative movement of the surface points simultaneously on the entire object of study. The relativity of the movement rises from matching of two speckle images (reference state and recording state, the principle ESPI see Figure 1), both recorded by one CCD camera, when the object is illuminated by two flashes of the pulse laser. The speckles are dark and bright points in the image; they are the results of the interference effect of both the reference and from the rough surface scattered laser lights.

![Figure 1: ESPI principle (left); the speckle in reference and recording images (middle, right), schema of a phase shift between object and reference beams (up), schema of a first flash delay t1 after zero crossing of excitation signal and the laser pulse separation time Δt (bottom).](image)

The correlation of both images gives intensity pattern with fringes (contour lines at positions with equal extent of deformations). From its intensity the phase image could be determined (phase includes information also about direction of the movement). When ESPI user defines borders of the independently moving parts of the object, the phase image could have been mapped in a color scale from negative to positive maximum of parts movement (Figure 2). Since both the time delay t1 of the first flash after a defined triggering event (e.g. the zero crossing of excitation, see Figure 1) and the laser pulse separation time Δt are adjustable, repeating of double flashing after readjusting of t1 gives a possibility to follow the deformation changes in time.

![Figure 2: Boarders of independently moving parts (left); phase image (middle); color image and color scale of the changes of the surface deformation Δ within pulse separation time Δt (right).](image)

Measurement
Firstly, the acoustical frequency transfer function of the violin in far field was measured in anechoic room (see blue line in Figure 4). The violin was excited by the Dünnwald's transducer and harmonic signal (see Figure 3 left).

![Figure 3: The violin excitation with Dünnwald's transducer (left); schematic example of the series of the images collected at each particular frequency in one animated picture (right).](image)

Than, the violin body vibration patterns were observed by the ESPI Q-600 at frequencies marked in transfer function with red color points. Next, the series of the images with the vibration pattern (see Figure 3 right), recorded at each
particular frequency, were collected in one animated picture (the animations can not be presented in the form which has this article; here each pair of images presents this part of an animation which shows maximal changes of deformation).

Discussion

From images inserted in graph of frequency transfer function (see Figure 4) they are manifested the bands of frequencies are, where the vibration patterns are similar (from 350 to 500, from 550 to 700, form 700 to 800 Hz). It corresponds with large resonance hills in the graph. The image at 338 Hz picks up also a resonance of the tailpiece (its phase is shifted). Between 1 and 2 kHz the resonance of parts surrounding \( f \)-holes occur and distances of the resonance maxims in vibration patterns are closer. Round 2 kHz and above also the bridge has its own resonance. The images at frequencies 381, 536 and 1005 Hz depict the different types of a symmetrical vibration pattern. These patterns are nice from the aesthetical point of view, but they produce only low sound pressure level (notches in the frequency transfer function). Except the resonance at 271 Hz (cavity resonance), the main top and back plates movements go in the same direction (e.g. top up and back down). The cavity mode shows the plate motions with the opposite phase.

The presented ESPI method of the vibration visualization is very sensitive and useful for the study of string musical instruments. The violin excitation by the Dünnwald's transducer allows a long-term, stable and repeatable elicitation of the violin plate vibration pattern and also synchronized observation of movements of both the top and the back plate.

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References
