

THE CONNECTION OF THE VIOLIN BODY VIBRATION PATTERN AND THE VIOLIN FREQUENCY RESPONSE COURSE

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Abstract: The far field frequency response of the violin was measured in anechoic room. From response, the frequencies: of the resonance peaks, of the minima between resonance, and also of its surroundings, were chosen. The violin body vibration patterns, at some of those frequencies, were observed by the electronic speckle interferometer (ESPI). The patterns were compared, and the connection between the vibration patterns and the shape of the parts of the frequency response is discussed. In all cases the violin was artificially driven by the Dünnwald exciter.

1. Introduction

Several methods for a visualization of the violin body vibration are used in the studies about the influence of body construction on the quality of violin [e.g. 1, 2]. The double pulse TV holography method (electronic speckle interferometer – ESPI [3]) 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), both recorded by one CCD camera, when the object is illuminated by two flashes of the pulse laser. The speckles are the result of an interference effect of laser light, which is scattered at a rough surface (Figure 1).

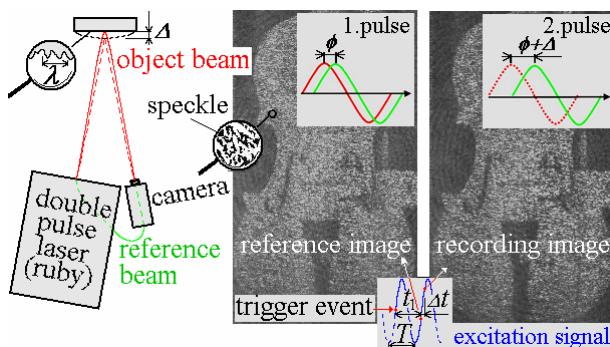


Figure 1. Schematic presentation of principle of the ESPI visualization.

As the object moves, the recorded speckles are also moved. The correlation of both images gives intensity pattern with fringes (contour lines, which represents points of the equal deformation) and 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 continuously in a color scale from negative to positive maximum of parts movement (Figure 2).

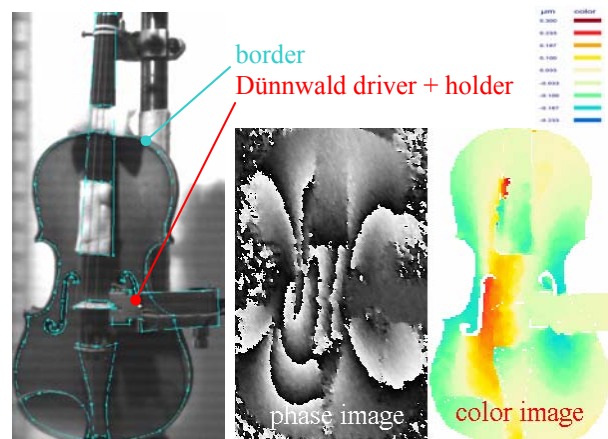


Figure 2. Violin + imprinted border; Dünnwald driver + holder; ESPI phase image and color image.

Since both the time delay (t_1) of the first flash after a defined event (e.g. triggering on the zero crossing of excitation or triggering on a certain level; see Figure 1) and the laser pulse separation time (Δt) are adjustable, repeating of double flashing gives a possibility to follow the deformation changes in time. Focusing on a vibration of top parts of violin, the ESPI method 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).

2. Method

The far field frequency transfer function of the violin (Schönbach manufactory, year 1904) was

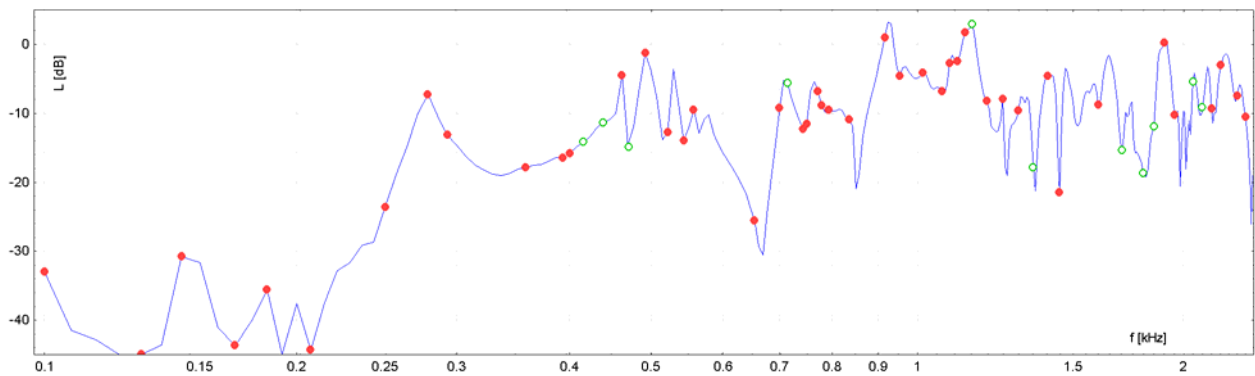


Figure 3. Frequency transfer function of the measured violin. The frequencies marked with color point were used for ESPI visualization (at red marked points the animation of diverse phase of surface deformation was prepared, see accompanying *animations.html* file; at green marked points only the “maximal” deformation pattern was captured).

measured in the anechoic room, in direction of the usual listening position, with artificial excitation by the modified Dünwald driver [4] (driver with its holder and violin with imprinted border see in Figure 2) powered by frequency generator (from 0,1 to 2,4 kHz). From that transfer function only the frequencies of the resonance peaks and of the minima between resonance (occasionally also other additional) were used for the next periodic violin excitation (see color points in Figure 3), when the ESPI visualization of the body vibration was run (ESPI device: Q-600 [3]). ESPI triggering was done on zero crossing of the excitation signal.

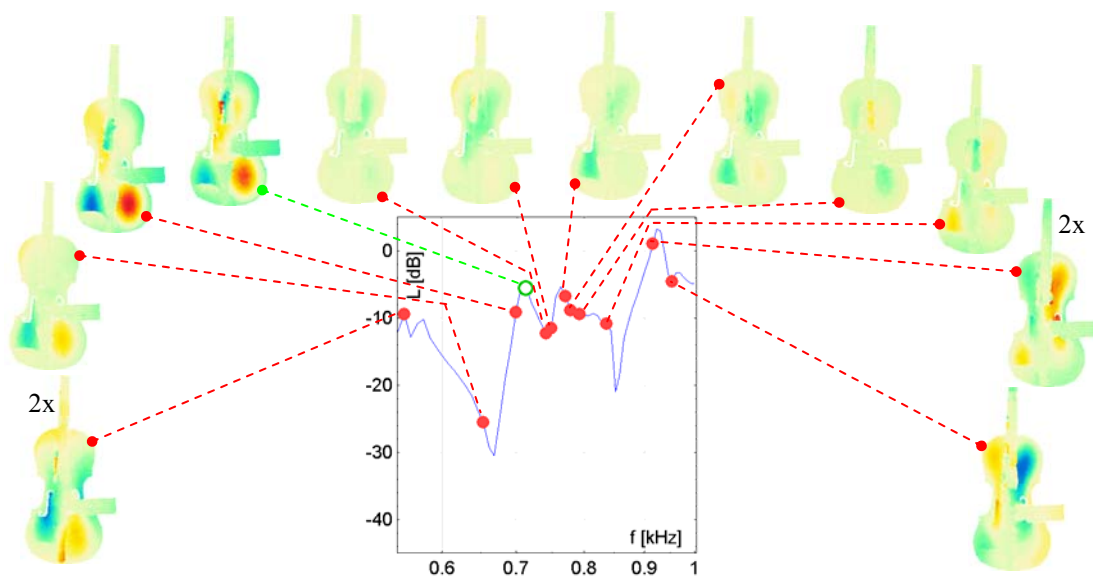
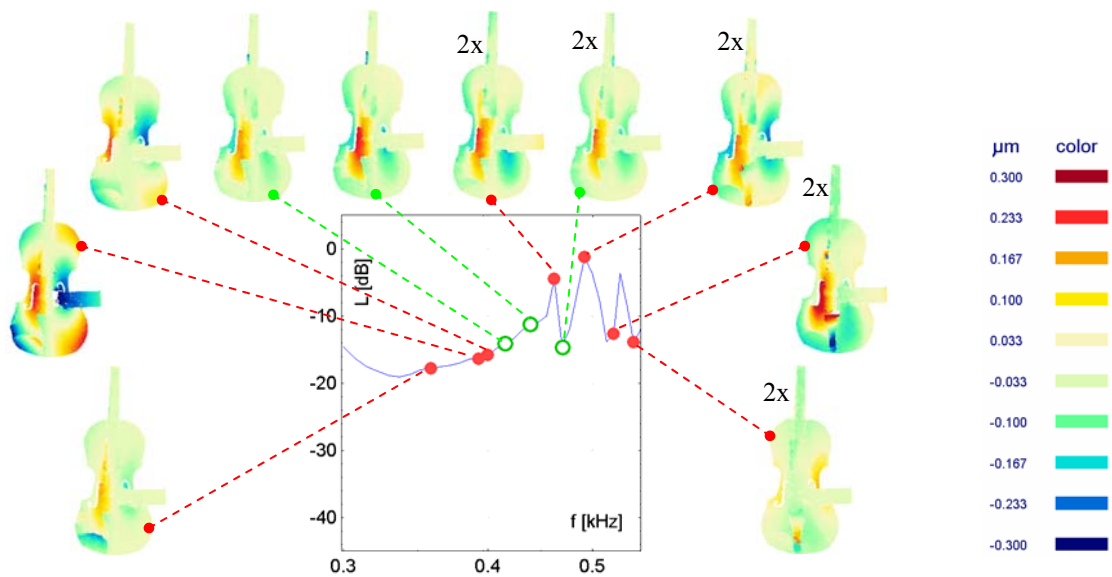
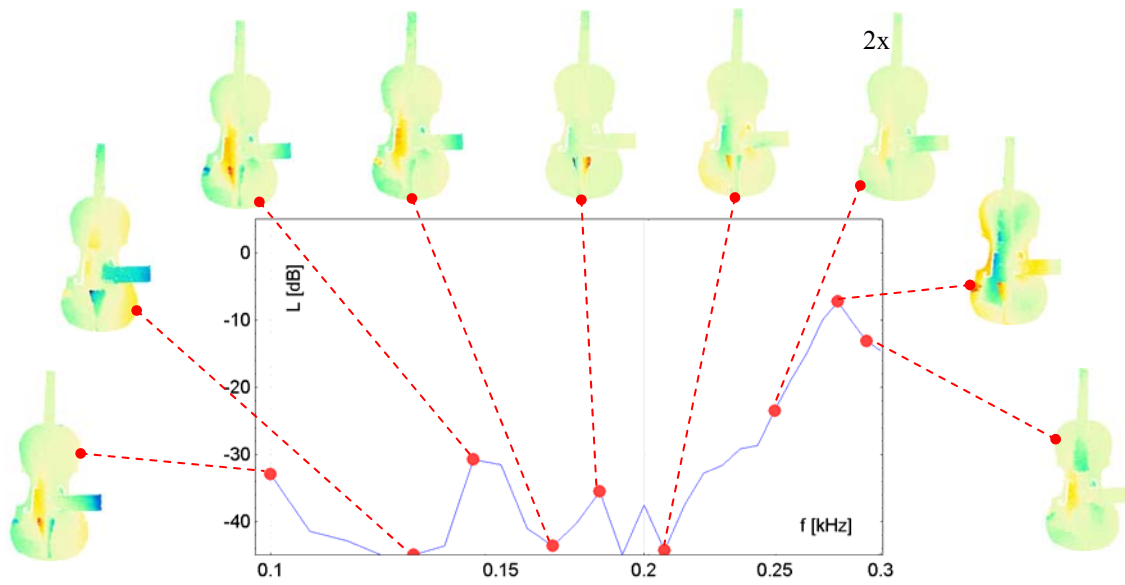
To make the particular images of the vibration pattern comparable, the time of the laser pulse separation was changed with frequency (to be constantly $\Delta t = T/20$) and the amplitude of the vibration at the artificial driver (at the violin bridge) was constant (except marked frequencies: Since ESPI method needs sufficient speckles in one fringe, the gradient of deformations can not exceed a level. At those frequencies, where surface deformations were too strong, the amplitude of excitation was reduced two times (see remarks 2x in Figure 4); in opposite, at frequencies above 2,15 kHz, where surface deformations were too low, the amplitude of excitation was two time higher (see remarks -2x in Figure 4).

Since the phase between the exciting signal and the vibration pattern changes with frequency (with respect to body resonance frequency), the time delay of the first flash (t_1) was initially at each frequency manually adjusted the way, to obtain at the image of a vibration pattern the minimum of the body vibration amplitude (this time was lettered t_{1i}). After that, the series of n images were ran with time delay $t_{1n} = t_{1i} + n \cdot T/10$ (n was usually 5, it represents the visualization of a half period of the body deformation).

3. Results and discussion

From each series of images at each frequency of interest only one image with highest vibration amplitude was chosen for the presentation of the type of the vibration pattern at particular frequency in Figure 4). All images of the each series were used for the animated trace of body vibration; see file *animations.html*, which accompanies this paper in the directory OTCENASEK of this CD-ROM.

In Figure 4 we can see wide bands of frequencies where the vibration patterns are similar (0,1 to 0,3; 0,42 to 0,55; 0,65 to 0,73; 0,76 to 0,83; 0,85 to 0,95; 1,05 to 1.17 kHz). It corresponds with large resonance hills in frequency transfer function. On the large resonance are local maxims, where the small parts of violin (tailpiece, chin rest, free end of fingerboard) have its particular resonance (it's phase is generally shifted). Above 1,1 kHz also resonance of parts of f -holes occur and distances of maxims in vibration patterns concentrate. Round 1,9 and above 2,15 kHz also the bridge has its own resonance. At low frequencies ($< 0,5 - 0,6$ kHz), where the half of wave length is longer than the size of the in coincidence moving parts of the violin surface, the efficiency of radiation is low. The same amplitudes of surface vibrations yield to lower sound pressure levels in the frequency transfer function (e.g. compare pattern and level at 0,2 and 1,23 or 2,1 kHz; accordingly, to make the weak vibration pattern at frequencies above 2,15 kHz recognizable, two times higher (-2x) amplitude of vibration excitation was used). The symmetry of the vibration patterns reduces also the level measured in far field (e.g. 0,39 kHz). The directivity of violin radiation above 1 kHz plays a significant role [5] and low level in certain direction could not occur in other direction (e.g. level and pattern at 1,45 kHz).



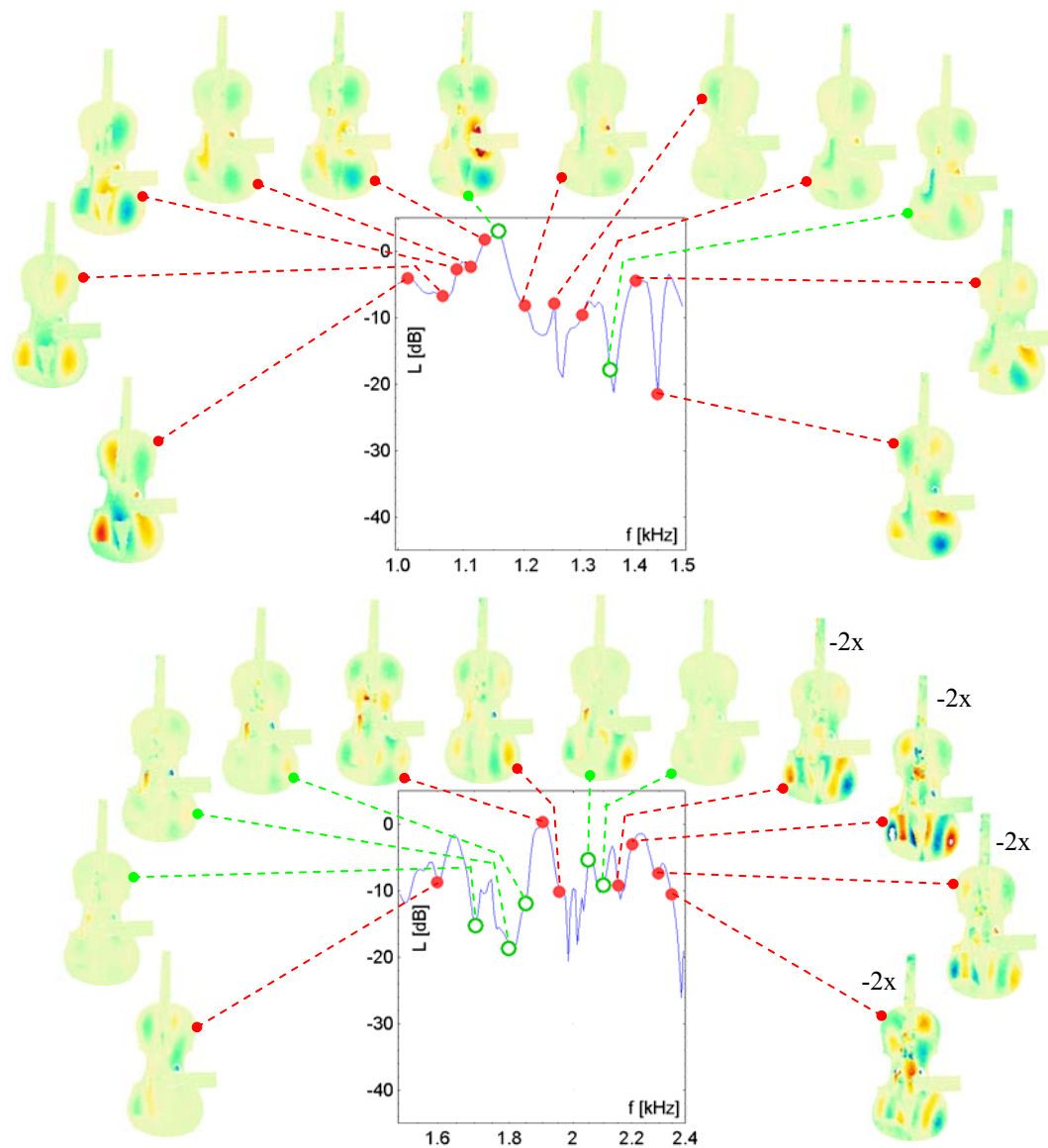


Figure 4. The violin body vibration pattern at particular frequencies connected with frequency response course (frequency scale from Figure 3 is here divided in 5 separate parts, each surrounded by pertain vibration patterns).

4. Conclusions

The ESPI visualization of the vibration is very useful method for the study of string musical instruments. The animations of the sequentially captured ESPI pictures (see: double click on the file *animations.html* in the directory *OTCENASEK* of this CD-ROM; the animation runs after a single click on the color pattern picture marked with red point) allow to study also the mutual moving of surface parts, which differ in phase of motion. The following research will be oriented also on the mutual moving of top and back plates.

Acknowledgements

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