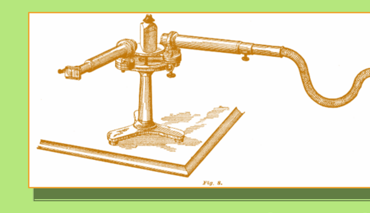
The analysis of the influence of optical absorbance on photothermally induced surface temperature variations in a thin sample of high optical transparence

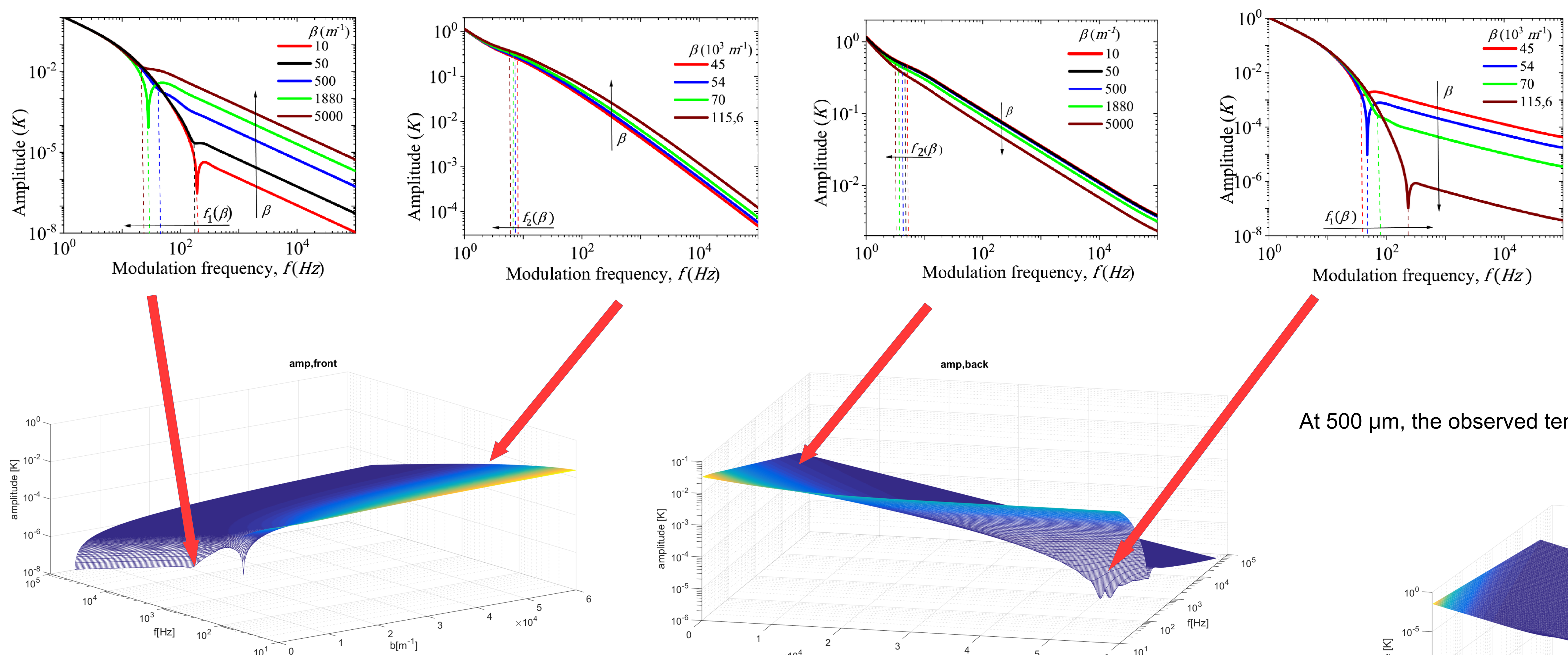
PHOTONICA 2023

M. Nesic[1], M. Popovic[2], S. Galovic[1], V. Miletic[3], Lj. Kostic[4]
[1]Vinca Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Belgrade
[2]Institute of Physics – National Institute of the Republic of Serbia, University of Belgrade, Belgrade
[3]Faculty of Philosophy – Pale, University of East Sarajevo, Sarajevo
[4]Faculty of Sciences and Mathematics – Department of Physics, University of Nis, Nis
e-mail:mioljub.nesic@vin.bg.ac.rs

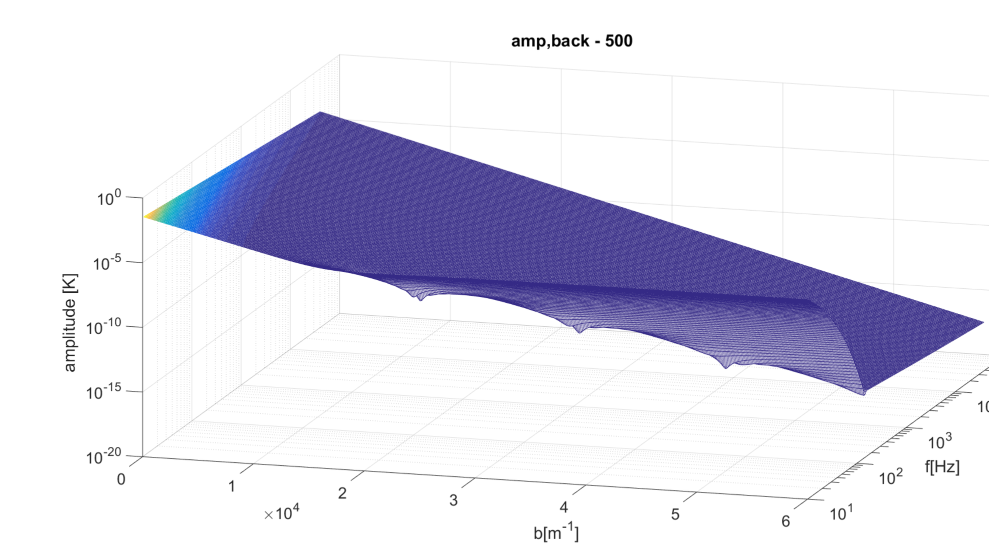


In transmission gas-microphone photoacoustics, in order to protect the microphone and improve the Signal to Noise Ratio of the experiment, a thin non-transparent layer is applied on the surface of the sample. When the applied layer is not illuminated – i.e. the incident light is passed through the sample, instead, and all the transmitted radiation is absorbed at the non-illuminated side of the system – optical absorption properties of the sample are preserved in the recorded photoacoustic response [1], [2], [3]. Thermoelastic component of photoacoustic response is based on the integral of temperature distribution in the sample. However, in the described configuration, the amplitude ratio and the phase difference of surface temperature variations can notably influence the direction and the intensity of the thermoelastic movement of the sample, thus modifying the induced photoacoustic response.

Herein, the analysis of surface temperature variations is done, aimed at the prediction of thermoelastic component of the induced photoacoustic response, and the sensitivity of the described model to the alterations of optical absorption coefficient is analyzed and discussed.

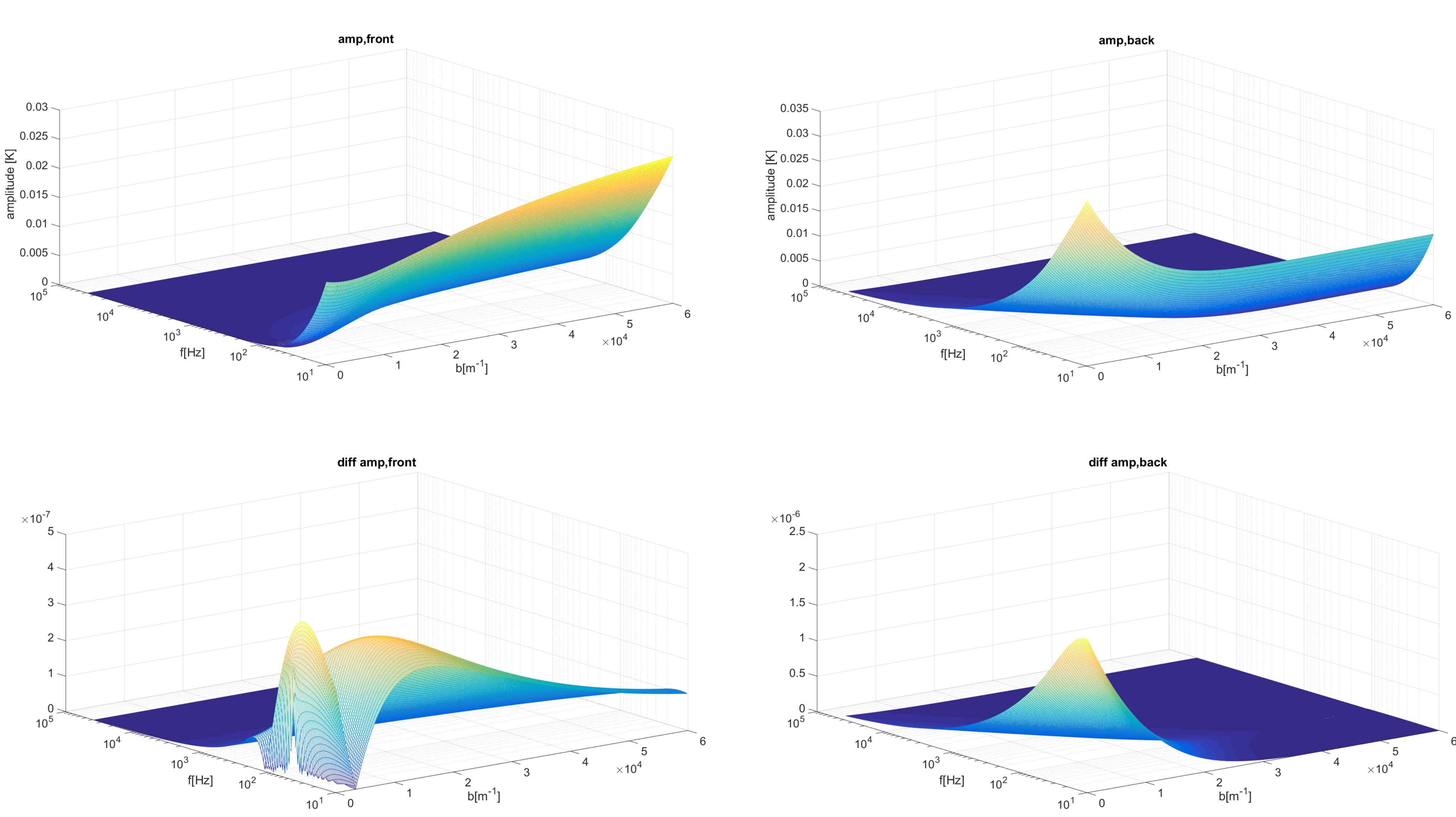


At 500 μm, the observed tendency continues:



Amplitude of surface temperature variations

In front amplitude, as presented in [2], at low levels of β, certain local minima as well as line shape changes occur. Similar peaks occur at high levels of β in back amplitude of STV. Herein, these phenomena are illustrated in logarithmic scale, and presented as the function of linear β change in 3D plots.



However, the occurrence of peaks in logarithmic scale is negligible due to their low absolute levels.

In order to gain insight into the real levels of amplitude change, expected amplitude levels are presented in linear scale below. Herein, the intensity of STV is shown to rise with the increase of β on the illuminated side (front), while at the same time decreasing on the non-illuminated side (back). The trend is in accordance with expectations: more transparent samples would let the incident light energy be deposited on the back side (and transferred to heat), while more opaque ones would keep the energy deposition closer to the front.

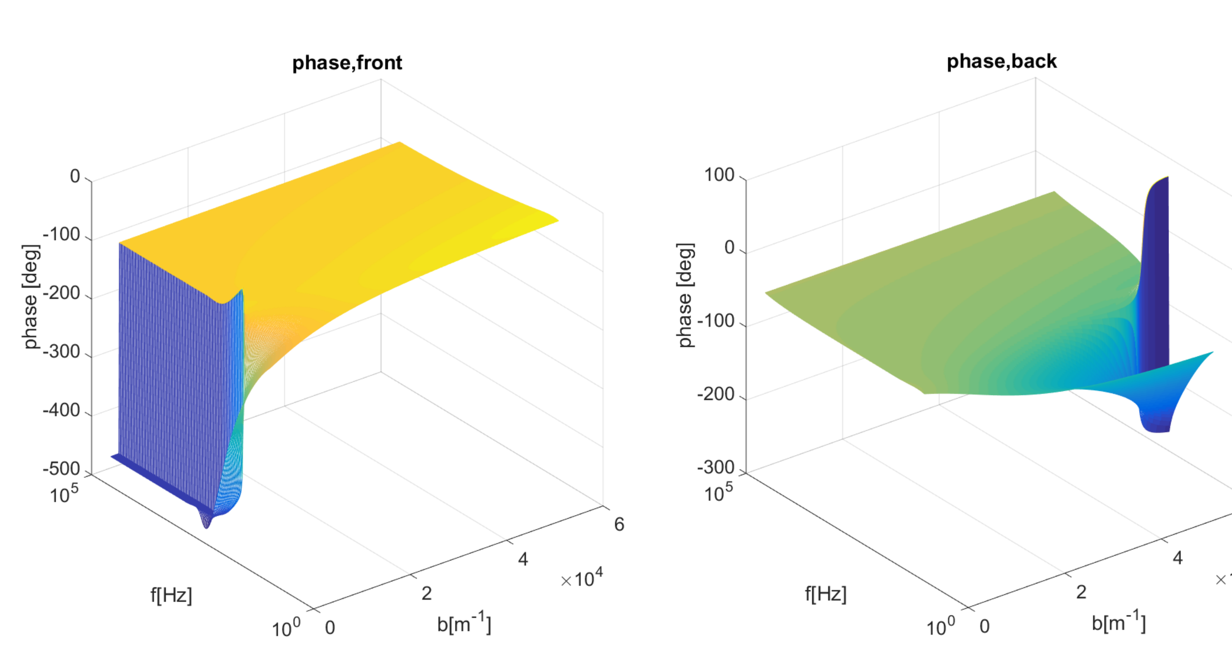
.

Front and rear amplitude sensitivity

The sensitivity of each of the observed amplitudes to the changes of β is calculated as the absolute value of the derivative in the direction of β. Herein, the conclusion from above is confirmed: the sensitivity of STV (both front and back) is higher at low frequency levels, while in the case of back STV it also drops at high levels of β.

Phase analysis

With the increase of β, phase change on front side is negligible, while notable change can only be observed on back side, at high levels of β:



Based on the obtained graphs, the conclusion can be made that the dependency of the changes in β are better observable at lower frequencies in SVT: on front side, this dependency is better observed at high levels of β, while on back side it is better for lower values of β. Although small in absolute value, several peaks emerge in logarithmic scale, making these images possibly well usable in shape recognition applications, based on neural networks.

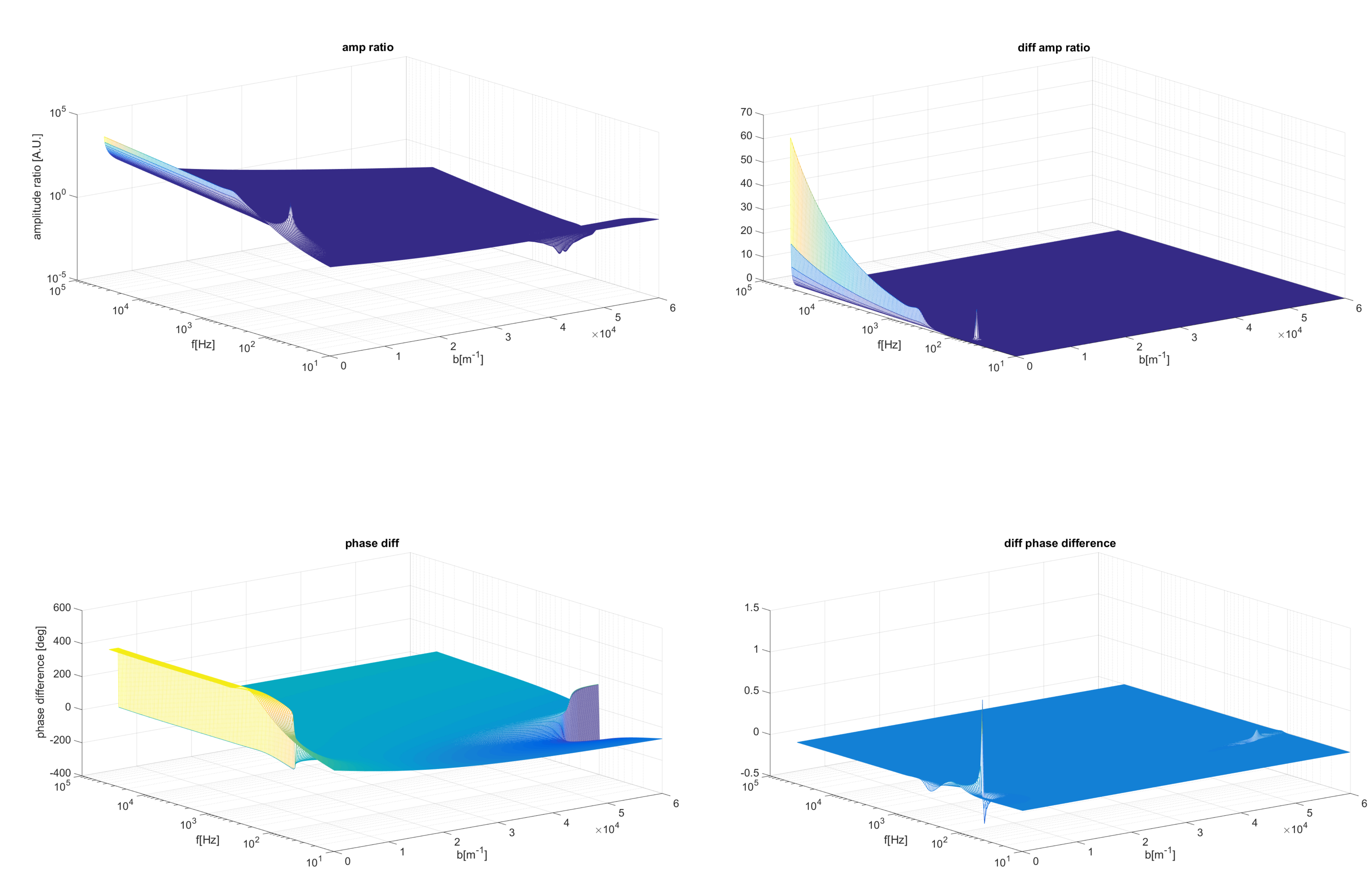
In optically opaque samples, thermoelastic component of the PA response is approximated well enough as the amplitude ratio of front and back STV. However, in the observed configuration, thermoelastic component is influenced by β in a more complex manner, and thus its sensitivity to the changes in β cannot be adequately assessed. This introduces the need for more accurate model derivations and further inspection.

Also, it is clear that differential approach, based on amplitude ratio and phase change, is not suitable for the determination of β.

Another conclusion is that reflection configuration may be more suitable for the determination of β, since therein PA response is not dominated by the influence of TE component.

Amplitude ratio, phase difference and their sensitivity

Although some sensitivity to β change is observed in front and rear amplitude of STV, as well as in back-side phase of STV, it is mostly lost in amplitude ratio and phase difference:



REFERENCES

[1] M. N. Popovic, M. V. Nesic, M. Zivanov, D. D. Markushev, and S. P. Galovic, Opt. Quantum Electron., vol. 50, no. 9, pp. 1–10, (2018).
[2] V. V. Miletic, M. N. Popovic, S. P. Galovic, D. D. Markushev, and M. V. Nesic, J. Appl. Phys., vol. 133, p. 075101 (2023).
[3] V. V. Miletic, M. N. Popovic, S. P. Galovic, D. D. Markushev, L. Kostic, and M. V. Nesic, Facta Univ. - Ser. Physics, Chem. Technol., vol. 20, no. 1, pp. 67–77 (2022).