# Validated Numerical Model And Simulation-Based Design Optimization Of A Photoacoustic Cell

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## Abstract

Photoacoustic spectroscopy (PAS) enables highly sensitive gas detection without optical detectors by directly measuring the sound generated from light absorption. However, the performance of PAS systems strongly depends on the photoacoustic cell's acoustic design. In this work, we developed a three-dimensional finite element model of a differential longitudinal photoacoustic resonator using COMSOL Multiphysics 6.3 and the Acoustics Module. The model was built with the Pressure Acoustics, Frequency Domain interface, included resonators, buffer volumes, and microphones represented by impedance boundary conditions. A frequency domain study yielded the resonance curve, which matched well with experimental measurements, validating the model. Based on this, we performed a simulation-based design optimization, varying buffer dimensions to study their effect on the signal-to-background ratio (SBR). As the changes targeted only the buffer volumes, significant variations in the Q-factor were not expected; however, SBR could be improved by reducing the background signal originating from background processes such as laser-window interactions. The workflow demonstrates the potential of COMSOL Multiphysics to design more efficient photoacoustic sensors and reduce prototyping iterations.

## Figures used in the abstract

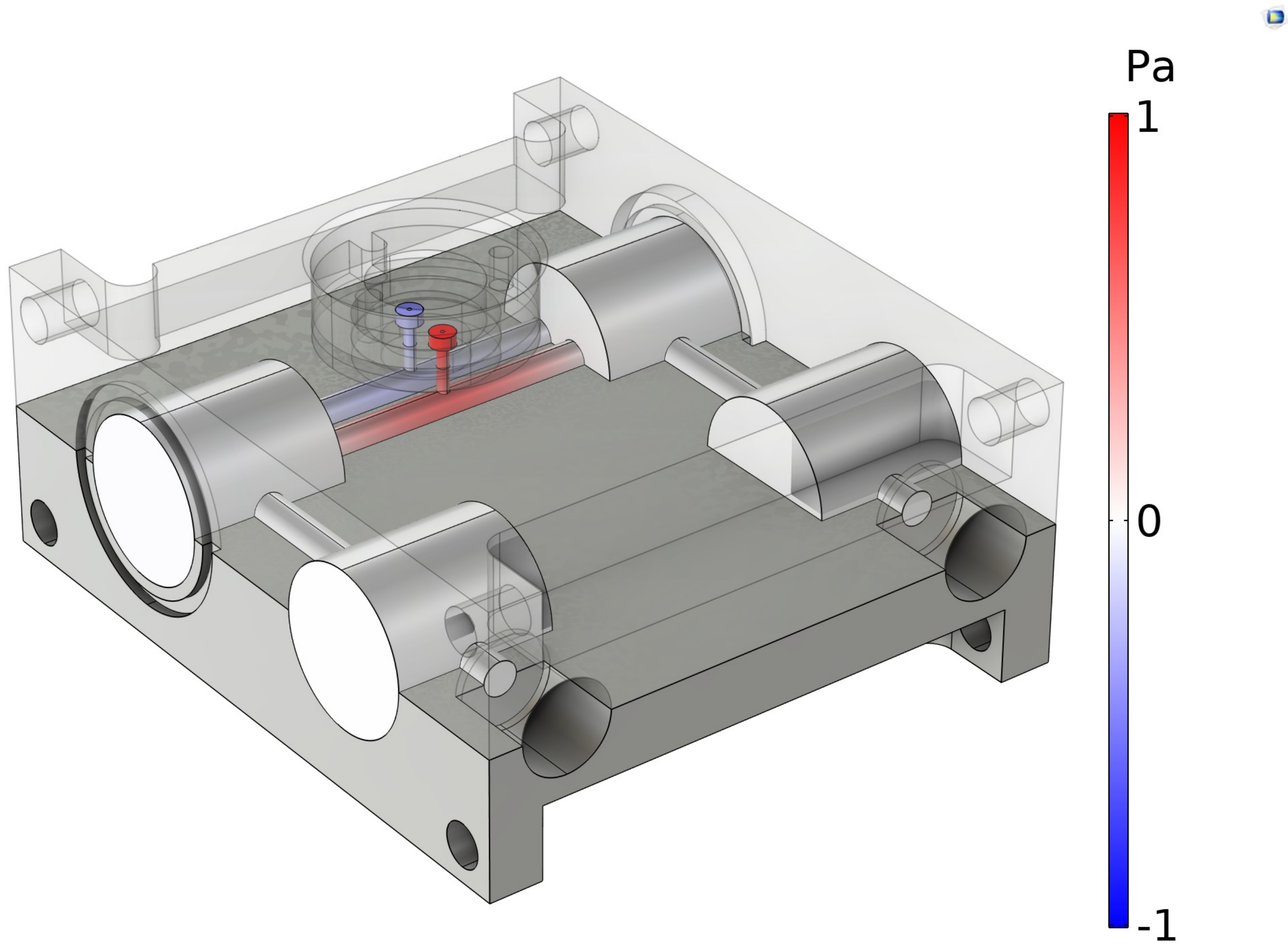


**Figure 1** : Normalized pressure distribution in the PA cell at resonance frequency.

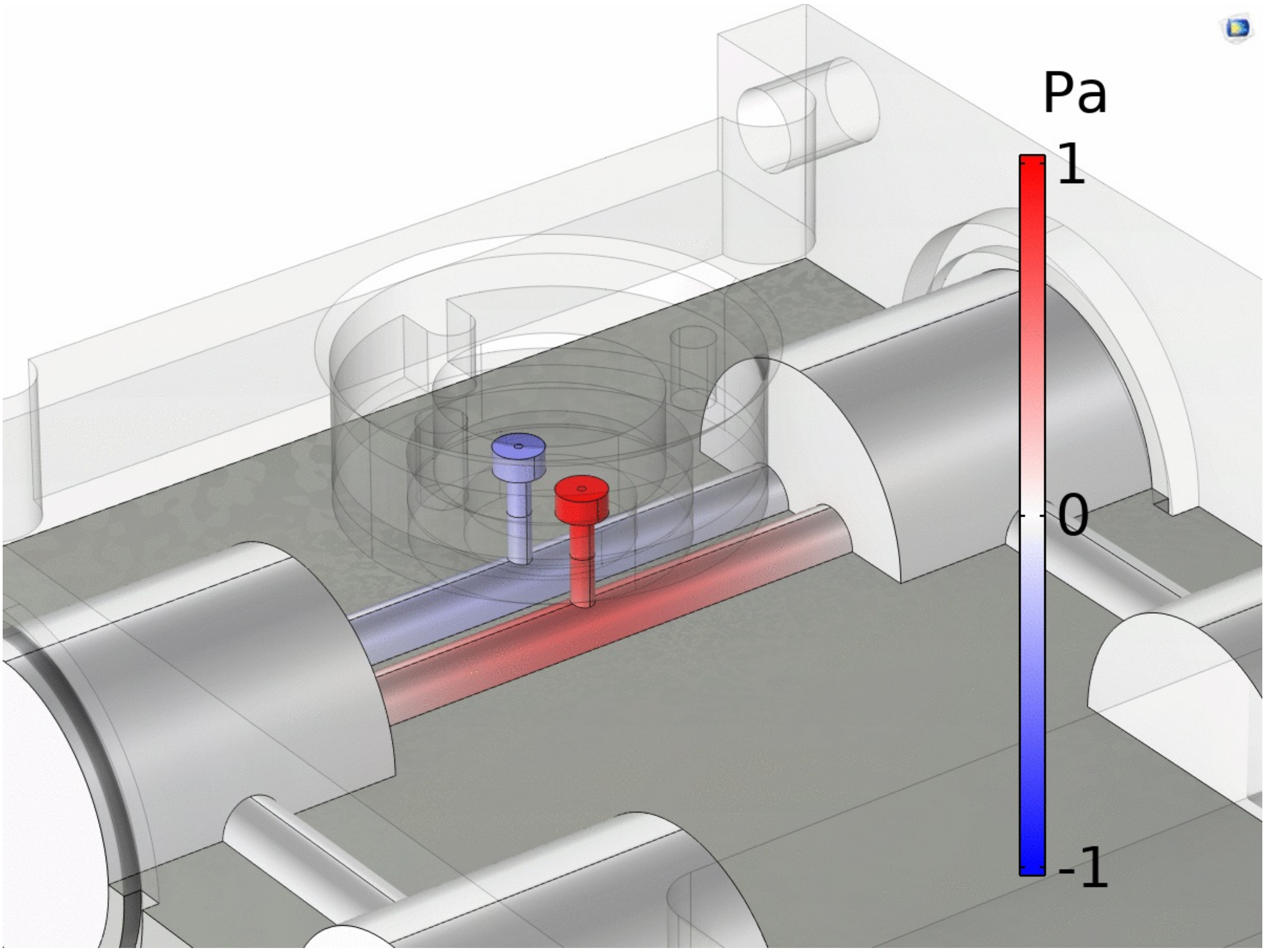


**Figure 2** : Pressure variations in the PA cell at resonance frequency.

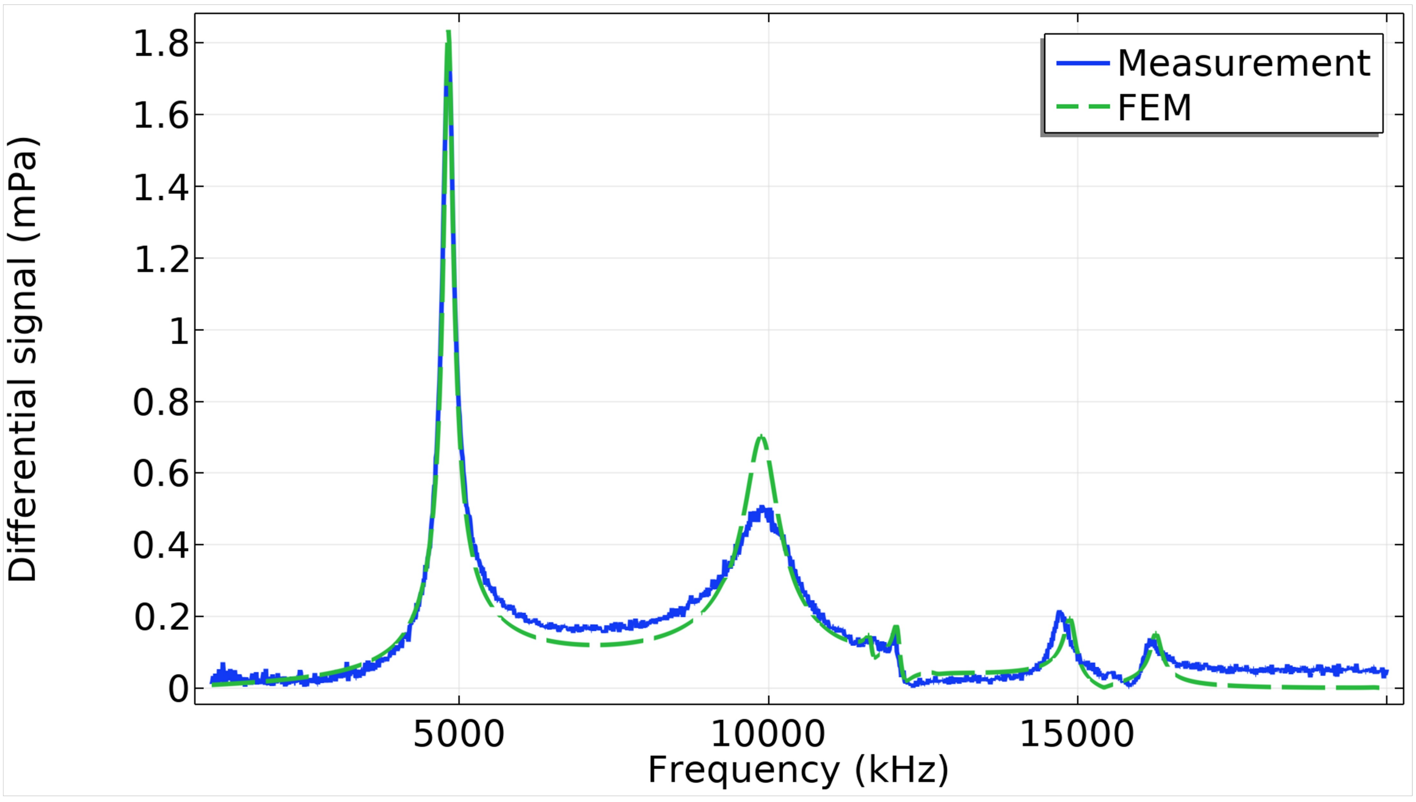


**Figure 3** : The resonance curve comparison between the FEM and the measurement.

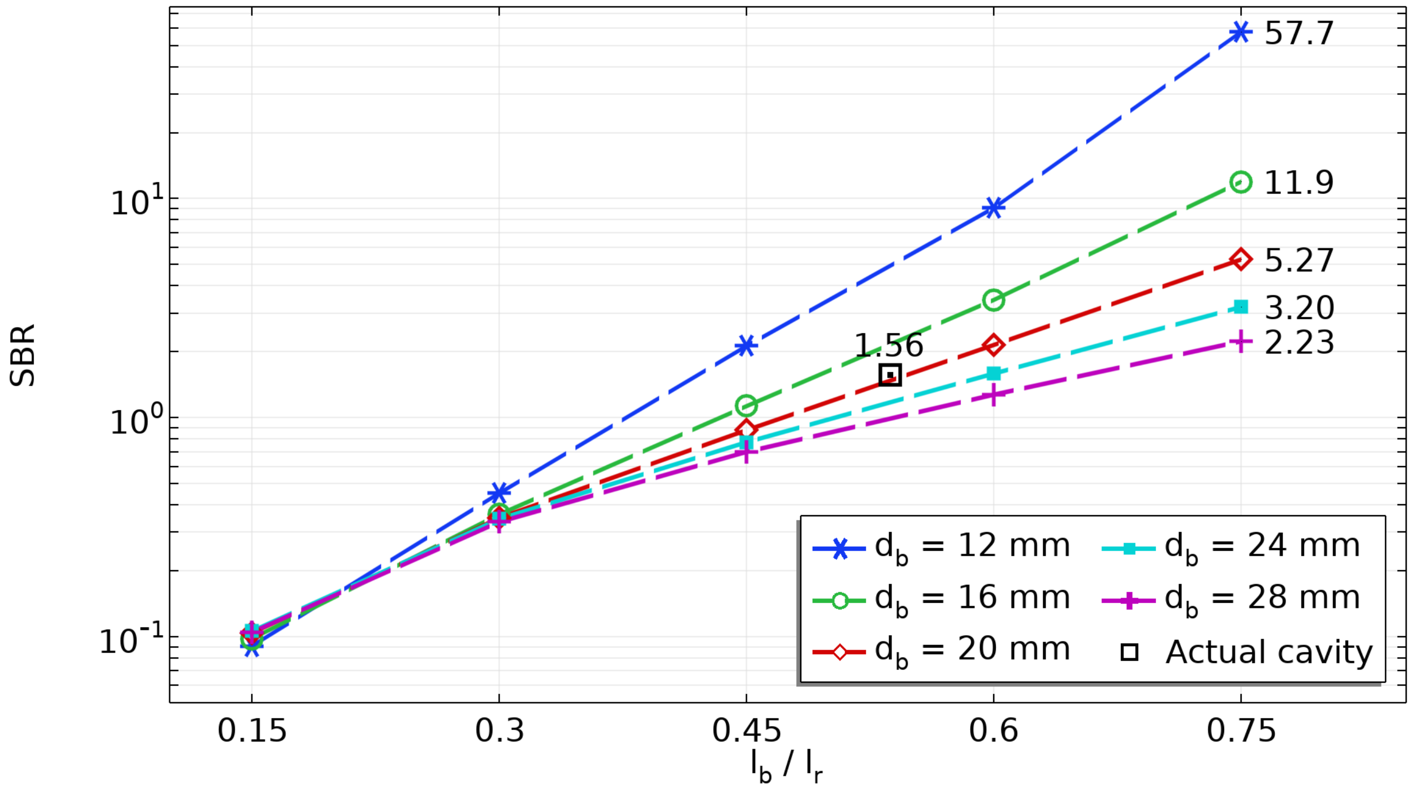


**Figure 4** : SBR as a function of buffer length (normalized by resonator length) for different buffer diameters.