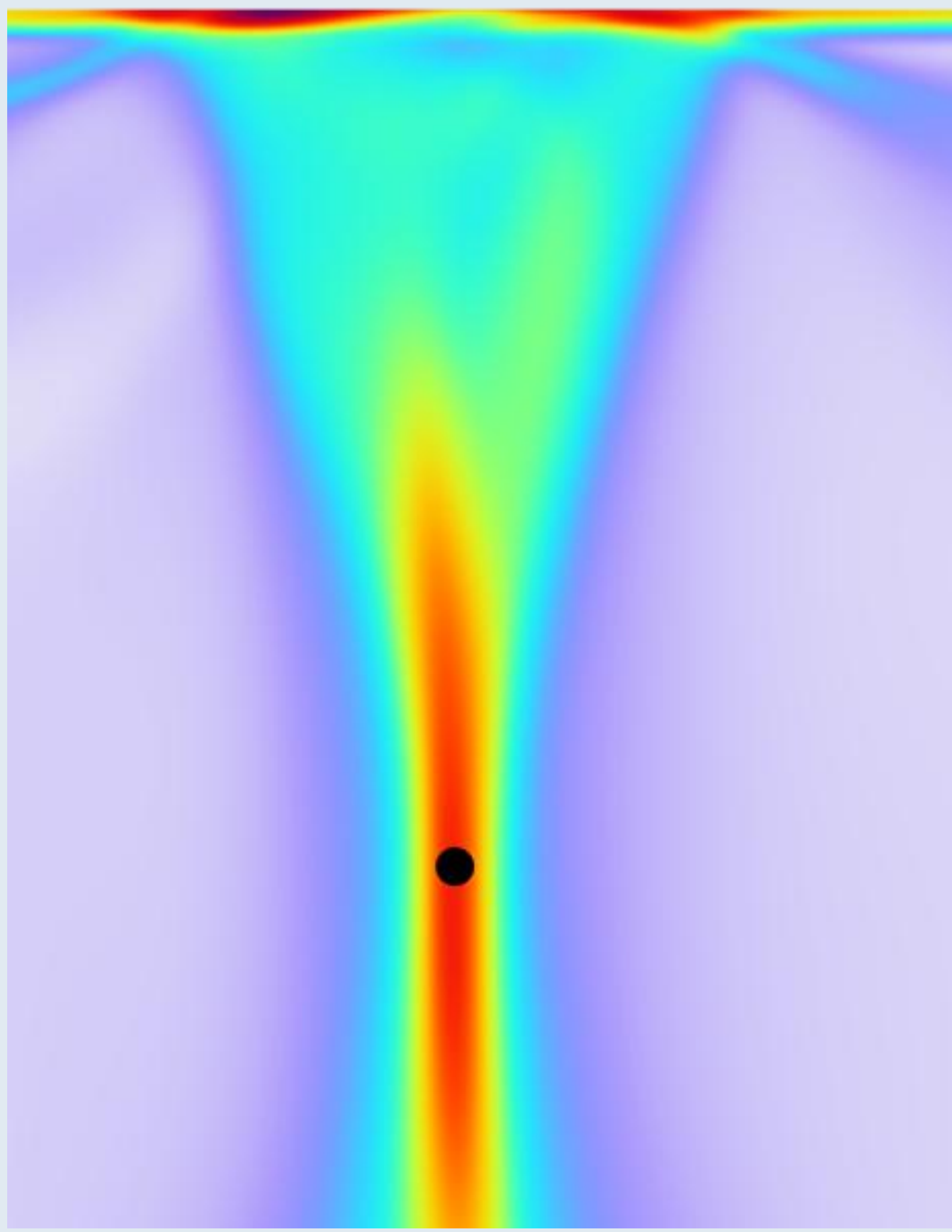




Real-Time Ultrasound Beamforming Apps Powered by DNN Surrogate Models

Interactive apps make wave physics tangible, but full finite element solutions of ultrasound propagation are far too slow for a responsive classroom experience — so we train DNN surrogate models on precomputed simulations instead.

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Introduction & Goals

Many physics topics are best understood by exploring them interactively, but the underlying simulations are far too slow to run live. This project develops a general workflow for turning such models into responsive teaching apps, deployed via COMSOL Server™ for students and teachers at our university.

Ultrasound phased array beamforming serves as the demonstrator here: interference of individually delayed element signals is central to nondestructive testing and hard to convey with static material.

The goal is an app in which the displayed field updates immediately when the steering angle, element count, or focal distance is changed.

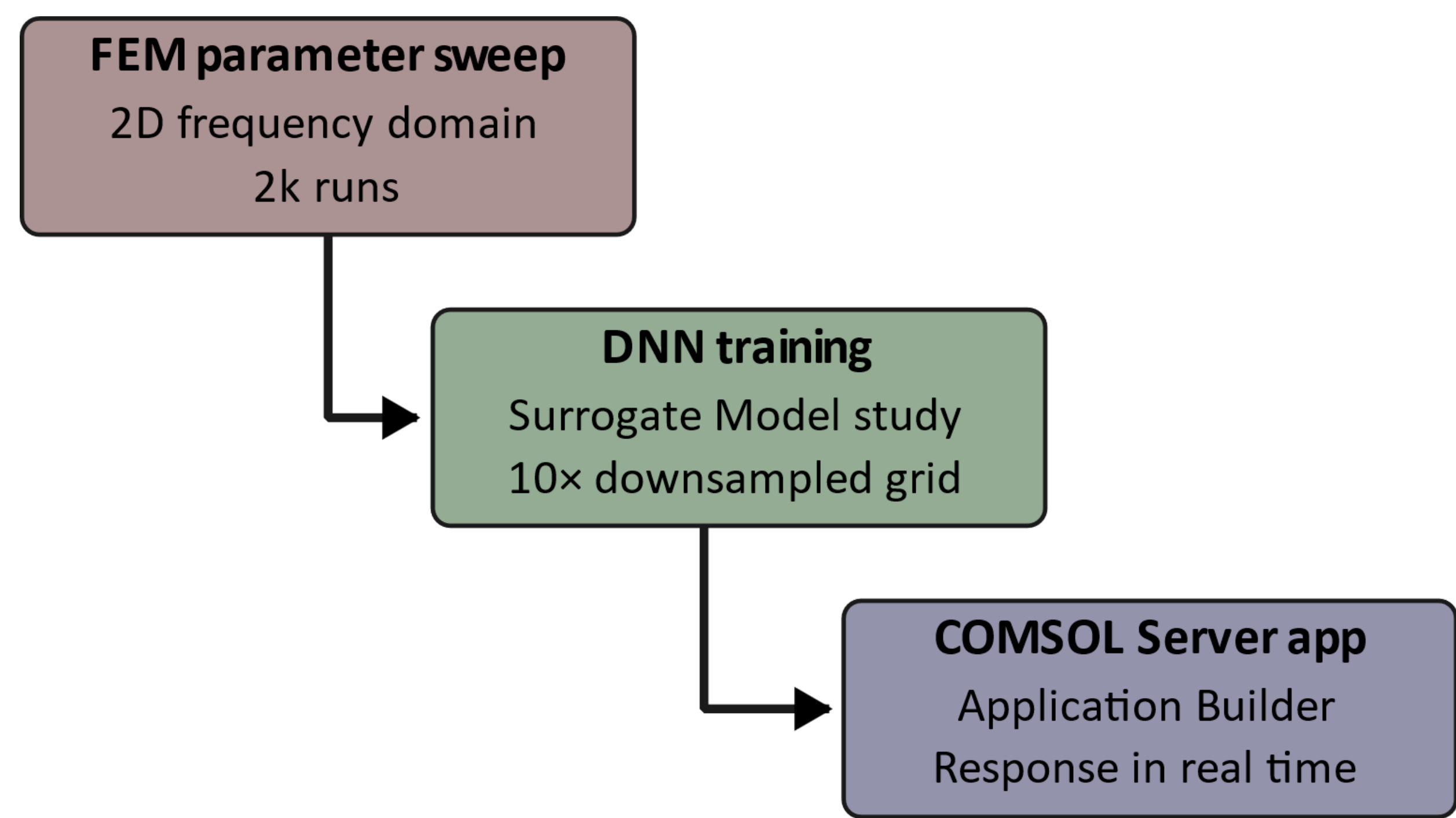


Figure 1. Training workflow.

Methodology

- FEM model** — A 2D frequency-domain model of a steel half-disc with up to 32 individually phased elements on the flat edge, built with the Solid Mechanics interface (Structural Mechanics Module).
- Training data** — 2000 solutions were computed over the steering angle, element count, and focal distance. Since the mesh resolves λ with five elements, training uses a 10x downsampled grid to improve speed.
- Surrogate and app** — A deep neural network (DNN) trained with the Surrogate Model Training study replaces the FEM solver inside an Application Builder app, served to students via COMSOL Server™.

Results

- Beam formation** — Simulated beam angles and focal positions match the prescribed inputs across the parameter range. Side lobes grow at larger steering angles, as expected for a steady-state field.
- Surrogate accuracy** — The DNN reproduces the field on the downsampled grid with a training and validation MSE of ≈ 0.012 and no signs of overfitting.
- In the app** — Field updates appear immediately when parameters are changed, replacing a one-minute solve. Internal trials were positive and classroom deployment starts next semester.

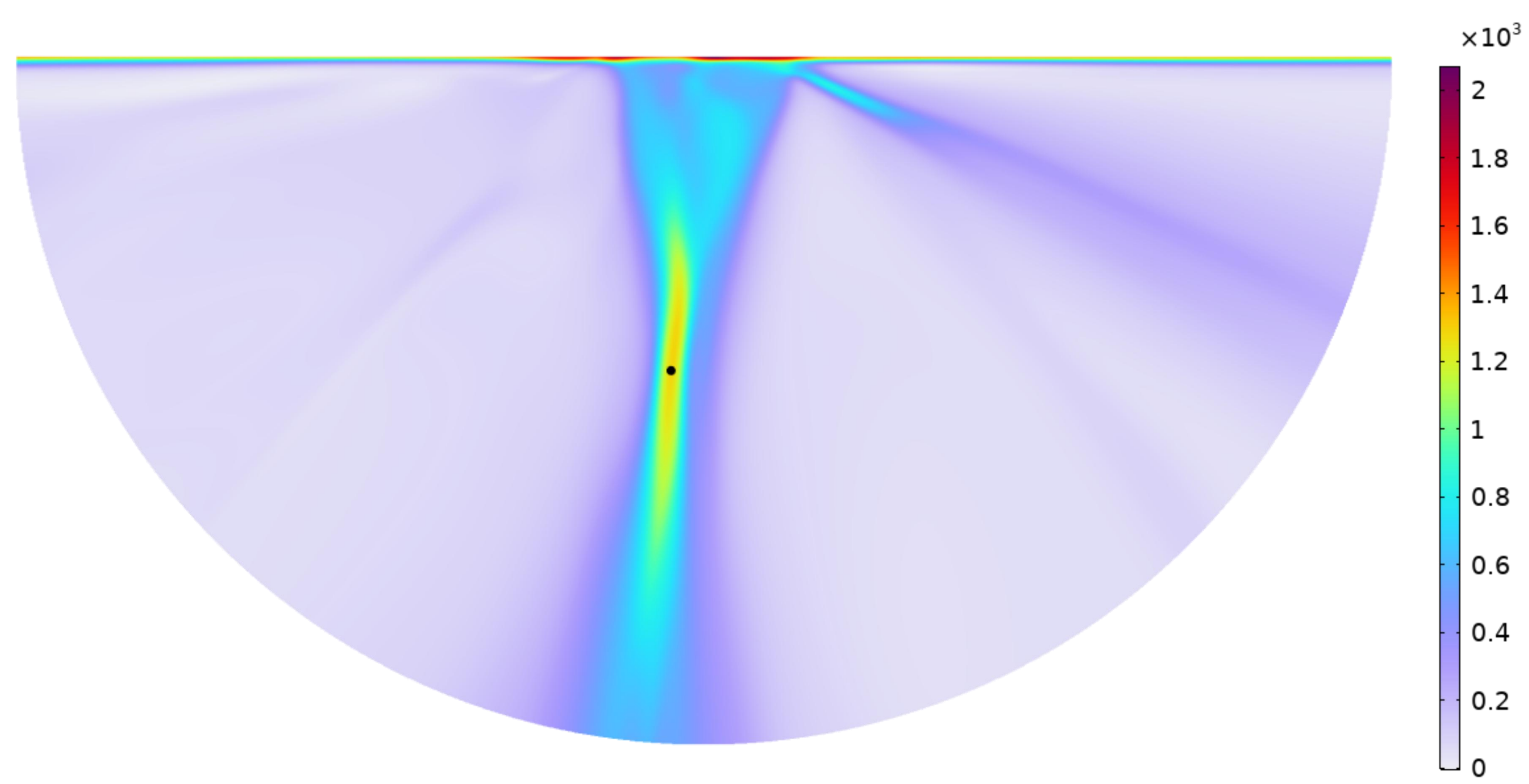


Figure 2. Von Mises stress predicted by trained DNN with target focal point shown (black dot).

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