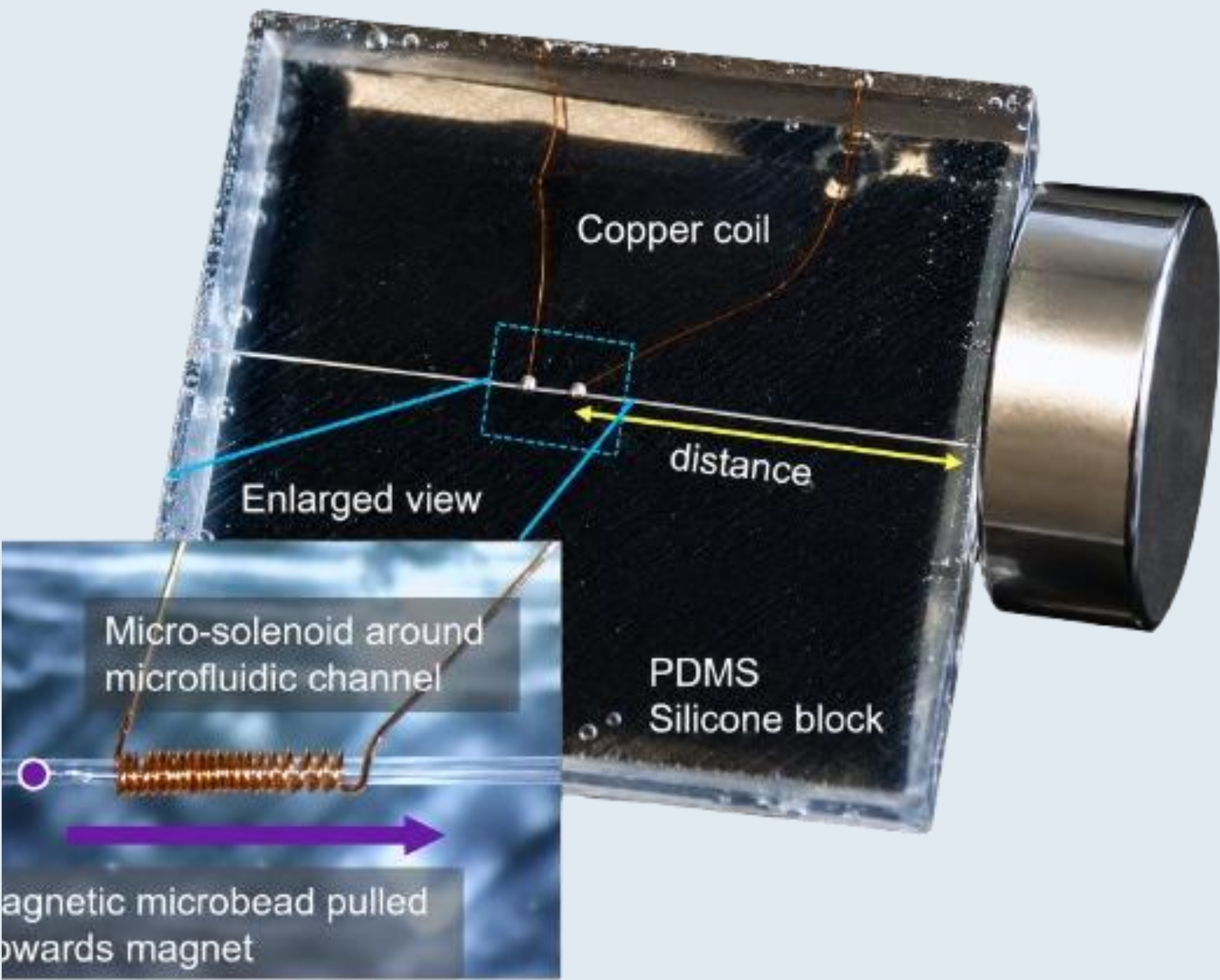




3D Modelling of Magnetic Microbeads for Biosensing

COMSOL Multiphysics® is used to simulate magnetic microbead behavior for next-generation microfluidic biosensing technologies.

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Abstract

Magnetic microbeads are widely used in microfluidic biosensors for target capture, separation, and manipulation; however, the transient nonlinear acceleration of a superparamagnetic microbead toward a permanent magnet and its effect on induced electromotive force (EMF) have not been quantitatively investigated.

This work seeks to present a numerical and analytical

study of magnetic bead dynamics in a three-dimensional microfluidic solenoid actuated by an external N52 neodymium magnet. COMSOL Multiphysics was used to determine the magnetic flux distribution, while analytical models were employed to calculate the dynamics of the microbead. The framework establishes quantitative design guidelines for optimizing permanent magnet placement and magnetic bead properties for inductive biosensing.

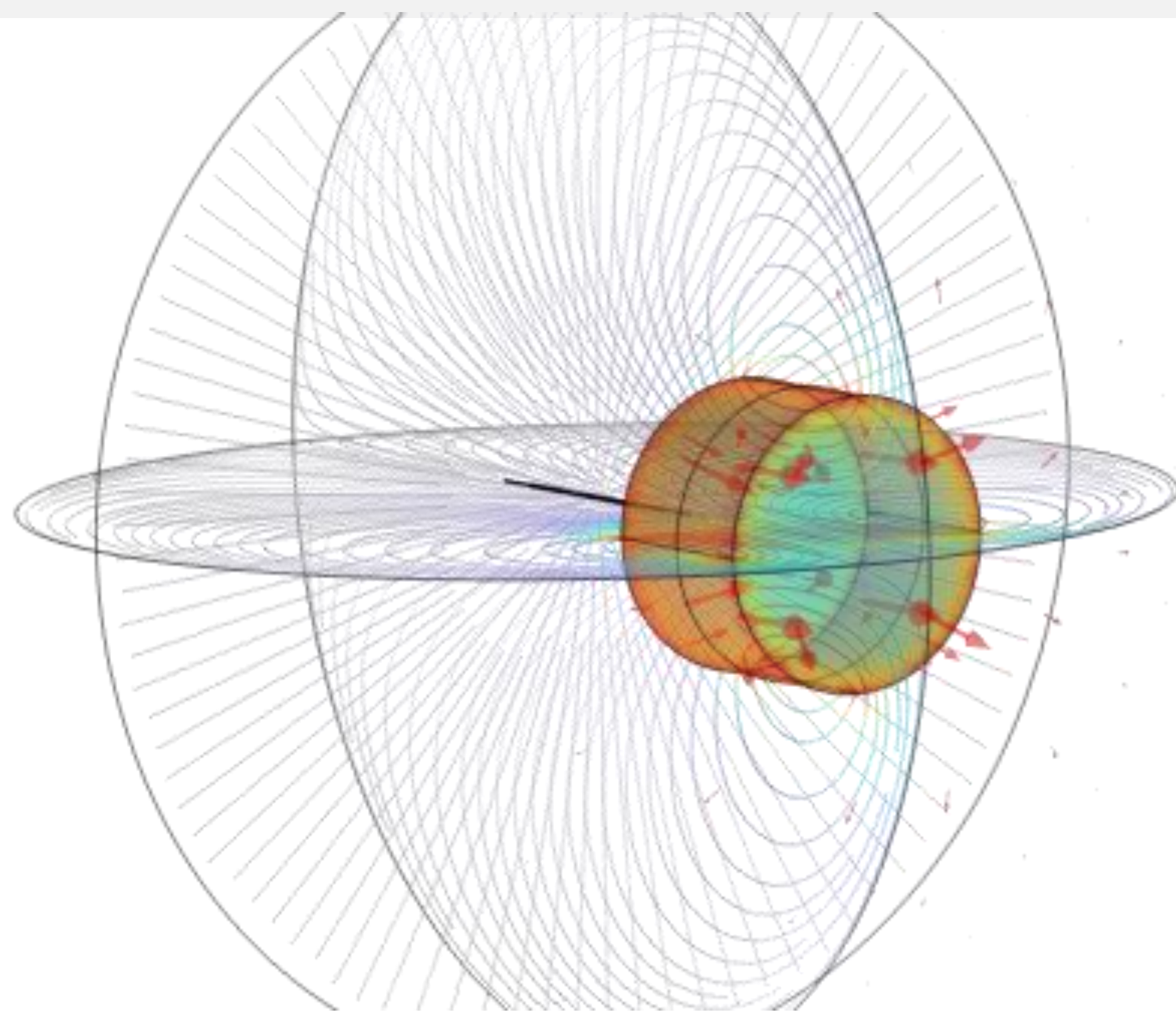


FIGURE 1. Magnetic flux density arrow surface from the permanent magnets within the air domain.

Methodology

A microfluidic channel with a length of 7500 micrometers was modeled separate from 2 N52 permanent magnets. An exterior air domain was then applied to the setup to prevent artificial flux insulation.

The magnetic flux was computed along the length of the channel using a cutline. A second order Lagrange interpolation was applied prior to numerical differentiation.

Data points were evaluated numerically utilizing the susceptibility based magnetic force equation:

$$\mathbf{F}_m = \frac{V_p(\chi_p - \chi_f)}{2\mu_0} \nabla(B^2)$$

Results

The results illustrate both a nonlinear increase in the magnetic flux density as well as the acceleration of the magnetic microbead as it progresses through the length of the solenoid.

With a time stepping procedure of 0.1 microseconds, boundary conditions set to 0, and the minimum acceleration applied, the bead reaches the end of the microfluidic channel in 0.27 milliseconds as a conservative upper bound.

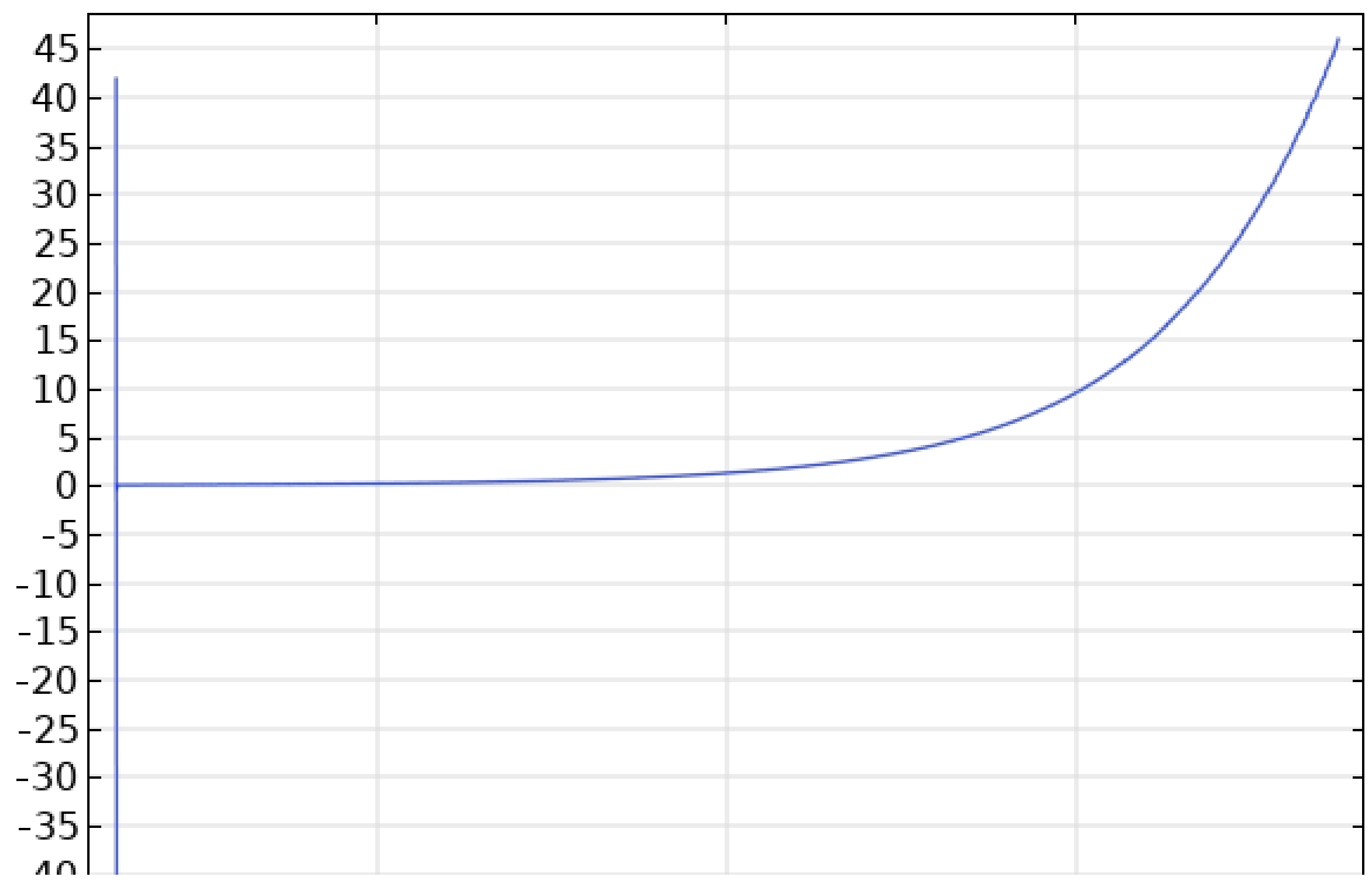


FIGURE 2. 2nd order flux interpolation plot, meant for export into numerical differentiation.

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