

## MECHANICAL ENGINEERING MSc SEMINAR (30 min.)

Thursday, July 13 2026 at 16:00-17:30, Lady Davis Building, Auditorium 250

### Thermocapillary Shaping over finite domains: high order finite-differences solver and linear control

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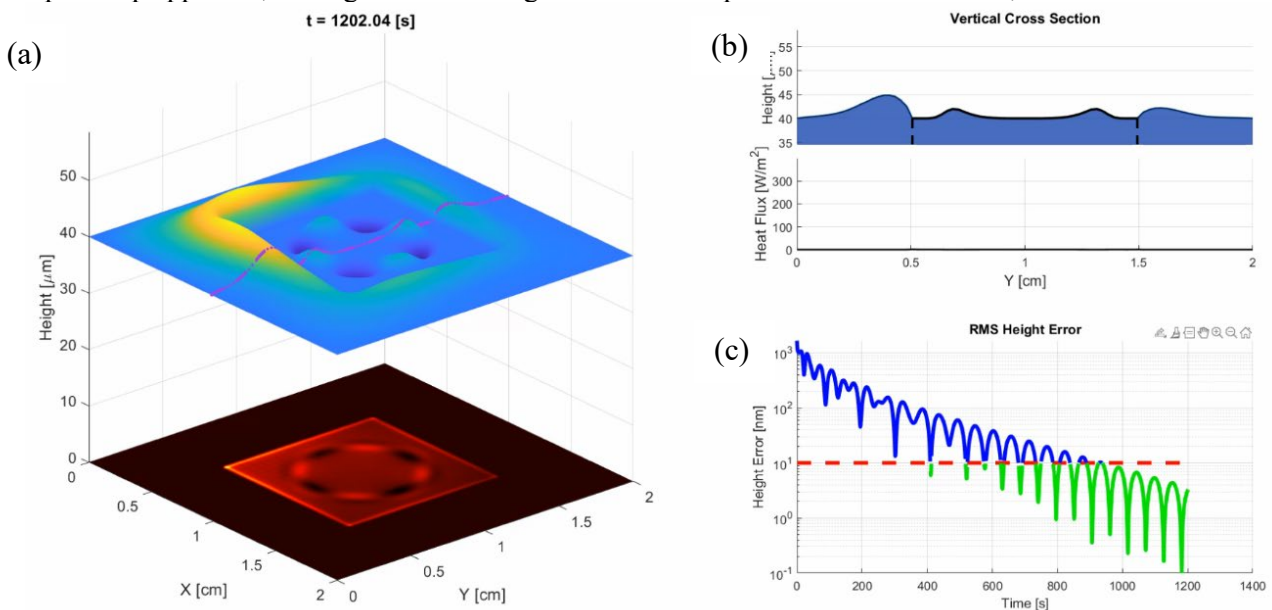
Adviser: Prof. Moran Bercovici

Thermocapillary Shaping is a novel method for fabrication of optical phase masks. By controlling the heat gradients on a thin liquid film's surface, we drive surface deformations via the thermocapillary effect. The underlying physics of this method is described by a highly nonlinear partial differential equation with Dirichlet boundary conditions (pinning).

We have previously demonstrated the viability of the method by subjecting a thin film to a heat flux from below, as prescribed by the steady state solution of our thermocapillary equation over an infinite domain.<sup>1</sup> However, the result, while consistent with theory, still exhibited non-negligible inaccuracies and required a long convergence time.

In this work, we present the development of a 2D dynamical numerical solver for simulated closed loop control of the Thermocapillary Shaping method in finite domains. We implemented closed-loop control via a PID controller that regulates the heat flux actuation at the base of the liquid chamber based on an array of surface topography measurements.

We show convergence rates two orders of magnitude faster than the previous open-loop approach, while achieving surface accuracies below 10 nm - as required for high-precision optical elements. Furthermore, unlike the open loop approach, our algorithm converges even with imperfect initial conditions, and volumetric errors.



**Figure 1. Close-loop shaping of a Zernike  $Z_{4,4}$  phase mask.** (a) Top blue surface presents the liquid's topography, influenced by the heat flux map seen on the contour below (red and black). The dashed purple line is the cross section shown in (b). (b) A cross section of the fluid and the projected heat map, the bold black line indicates the desired topography. (c) RMS height error as a function of time. The system converges below the 10 nm threshold within 20 minutes.