

Anomaly Detection in Floating Zone Single Crystal Growth

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Background and Motivation

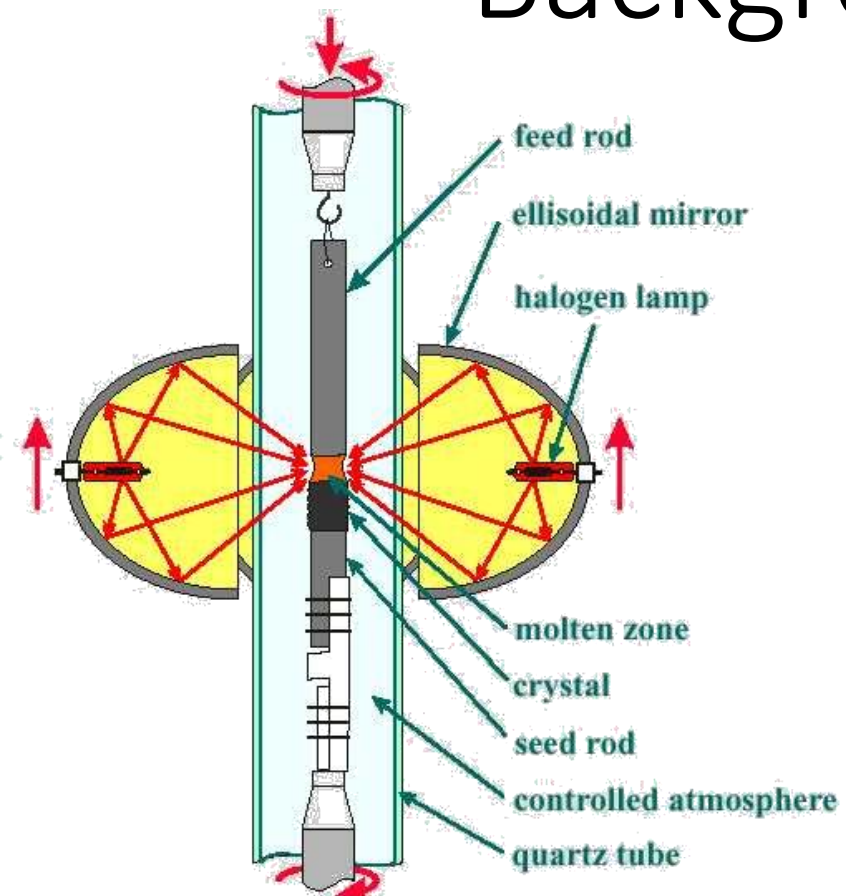


Image courtesy: Victor Jones, Harvard

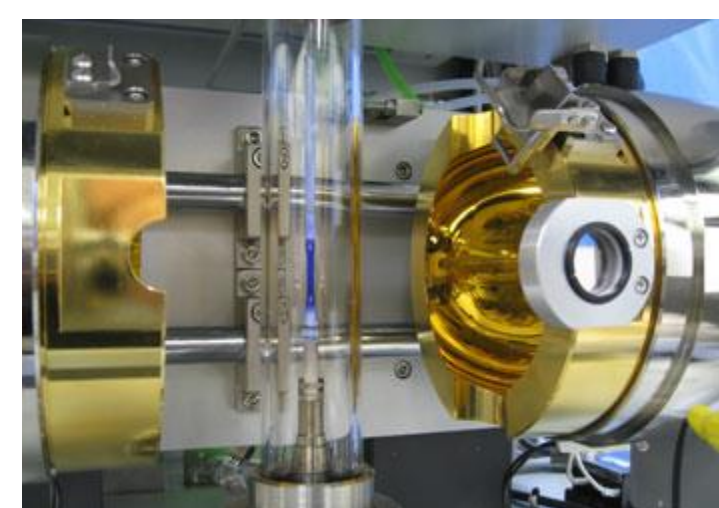
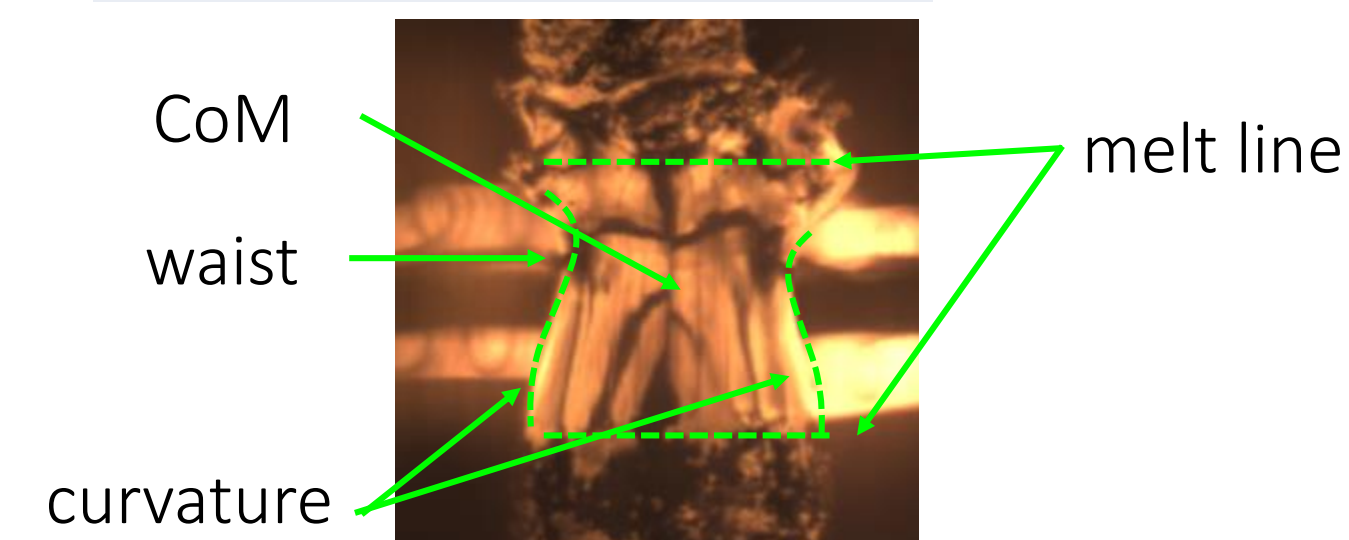


Image courtesy: Quantum Design Inc.

- Intense local heating either inductively (semiconductor) or optically (ceramics)
- Slowly moving molten zone stabilized by liquid surface tension
- Controlled melt-recrystallization process to achieve superior quality single crystal
- Heavily used in both **mature industry** (silicon) and **cutting-edge research** (superconductor)
- Monitoring and stabilizing the molten zone is **labor intensive** and inefficient
- Human perception doesn't work well to identify **subtle but accumulative** changes (often as slow as 1-2mm/day)

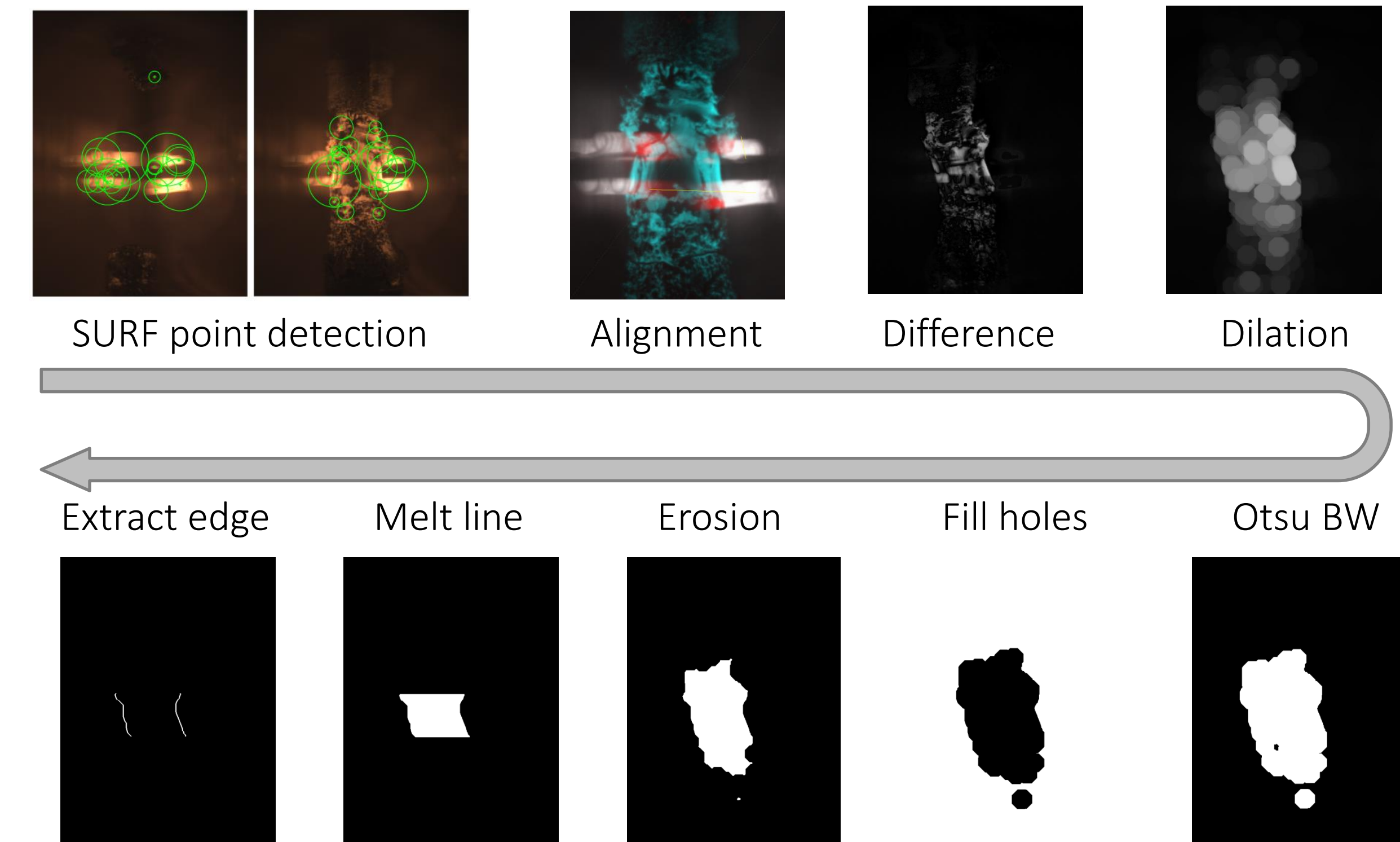
Foreground Extraction and Parametrization

Molten zone key ROI

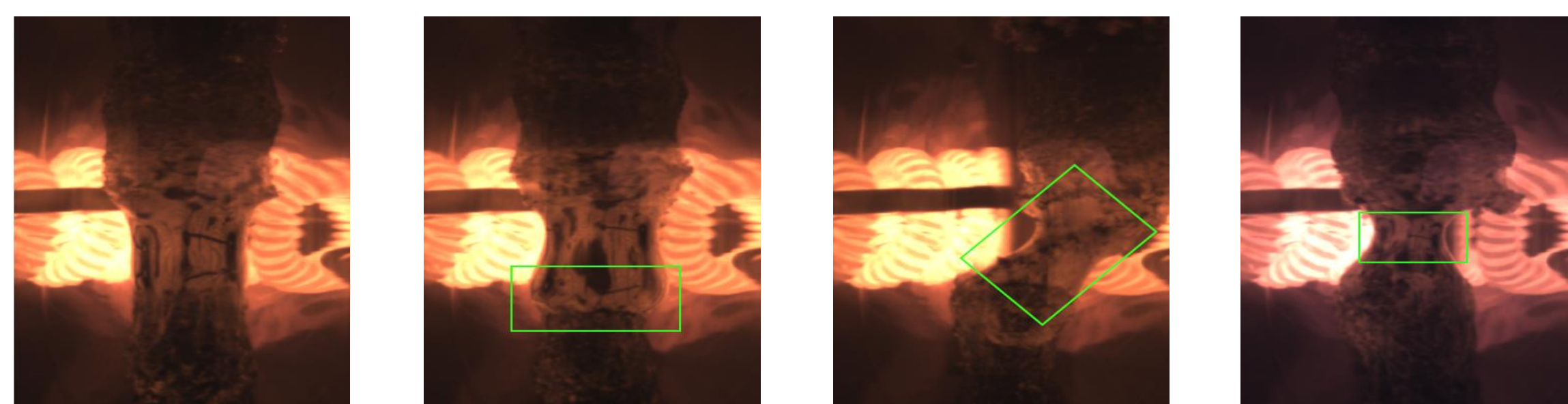


Main Challenges

- Foreground and background color schemes are similar
- Irregular dark reflections on the molten zone surface
- Bright reflections indistinguishable from background lighting



Typical Anomalies



	Ideal	Over-melt	Wobbling	Under-melt
Zone shape	straight or waisted	muffin-top	eccentric	thin-waisted
Zone volume	normal	increased	both ways	decreased
Center of mass	middle	down shift	horizontal shift	down shift
Consequence	OK	zone drop	zone tear	zone breakdown

Anomaly Detection and Prediction

- Different metric good for different property
- Additional metric (curvature, eccentricity) available
- Intuitively reflects slow steady but noisy trend
- 1-3 hours alert ahead of irreversible failure
- To-do: automatic melt line detection
- Integrate to motor control towards full automation

