SAND2007-4524C

CINT Microfluidic Synthesis Discovery Platform™

Nelson S. Bell, Team Lead
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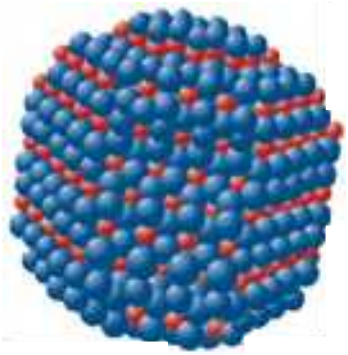
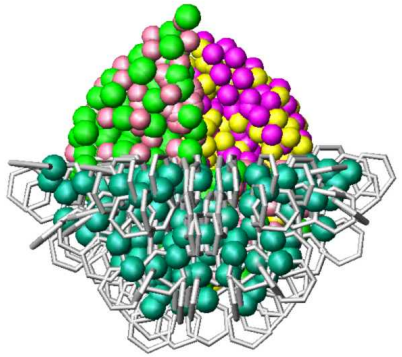




Commercialization of nanoparticle-based technologies:

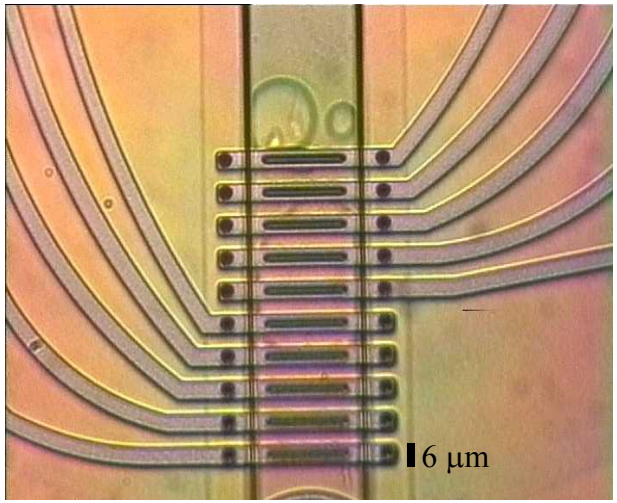
"…researchers are not focused on the requirements posed by scalable, cost-effective manufacturing. **Robust and reliable production methods are needed** to significantly expand the commercial use of nanomaterials."

"The largest barrier…is the lack of fundamental understanding…"

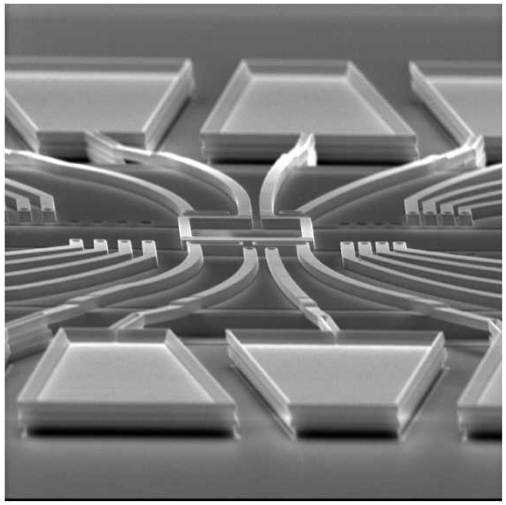
- Chemical Industry R&D Roadmap for Nanomaterials By Design (2003)

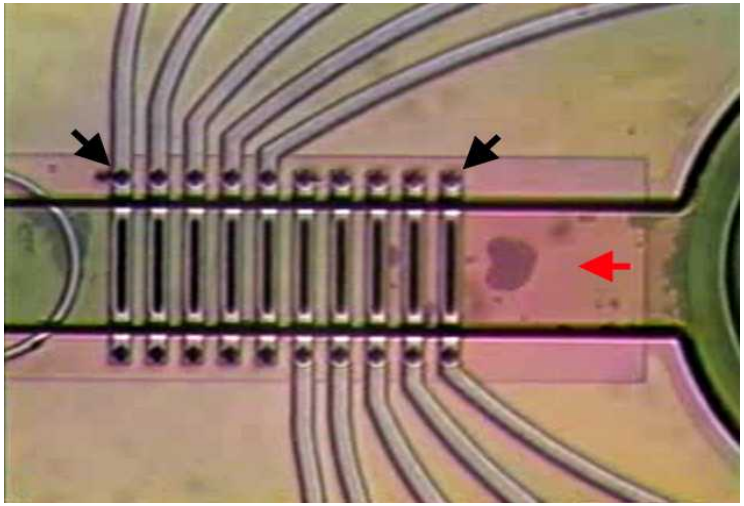
Opportunity for both science and technology

Electrochemistry/photochemistry – particle manipulation in microfluidic channels



electrolysis bubbles inside the channel





Trapping of beads by application of AC waveform (measurement by Conrad James, 1769)

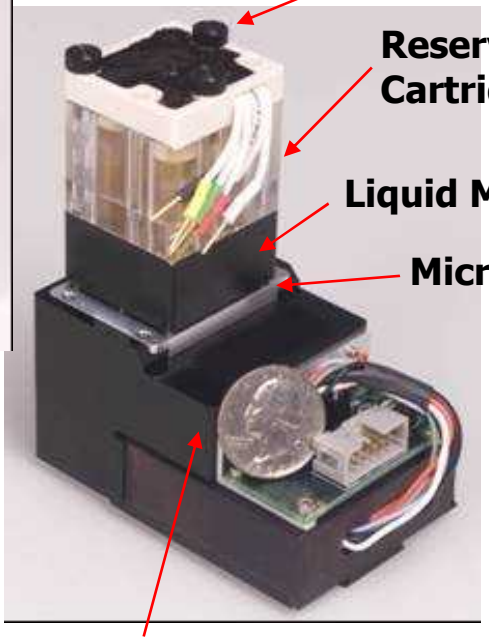
- Some of the very interesting aspects of micro-nanoscale reactions become observable/feasible at the scale of these devices.
- Reactions can be controlled by the applied field, light, temperature and flow conditions.
- Particles/streams inside the channel can be controlled by various means (dielectrophoretic trapping, magnetic fields, etc.)

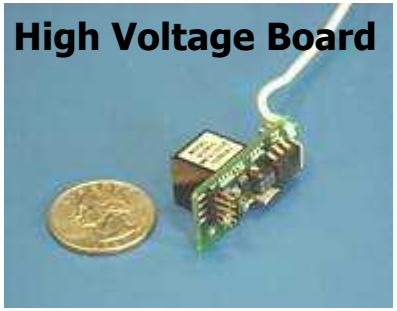
μChemLab technology enables rapid fluidic connections

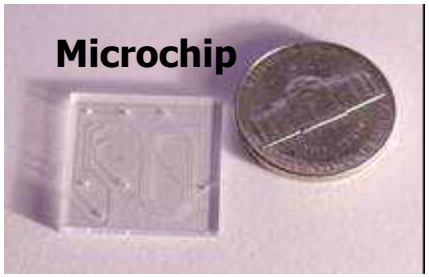
- Hand portable
- Battery operated
- On-board data analysis

A flexible, reliable platform for routine laboratory R&D

- Modular packaging
- Two analysis modules

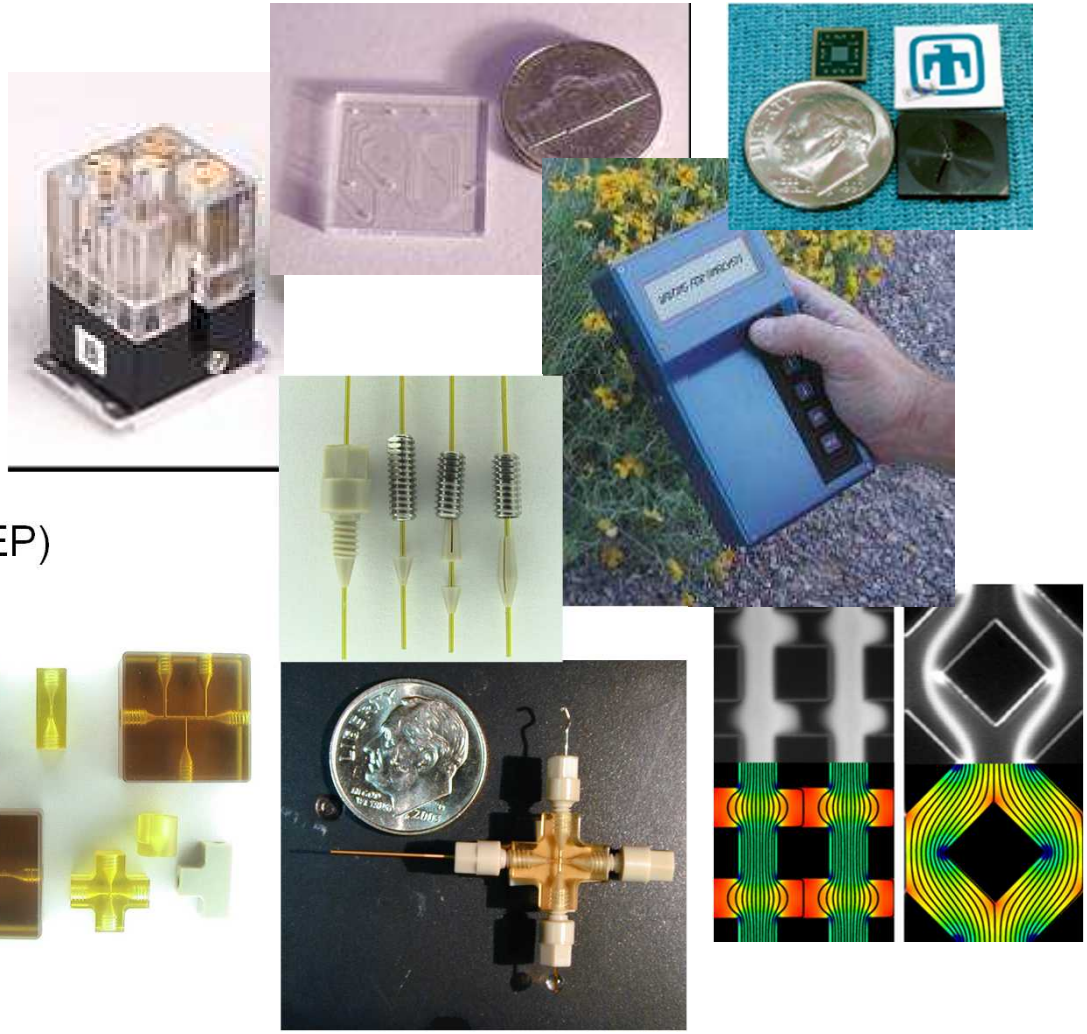






Microfluidic Technologies

- Capillary Chip Electrophoresis
  - CGE, CZE, IEF
  - Laser-Induced Fluorescence detection
- Electrokinetic Pumping
  - EK-High Performance Liquid Chromatography (HPLC),
  - Infusion pumps
- Insulator-based Dielectrophoresis(iDEP)
  - Particle concentration
  - Sorting
- Gas Chromatography
  - SPE, GC, SAW detection
- High Pressure CapTite Capillary Fittings
  - Sub-miniature
  - Reusable



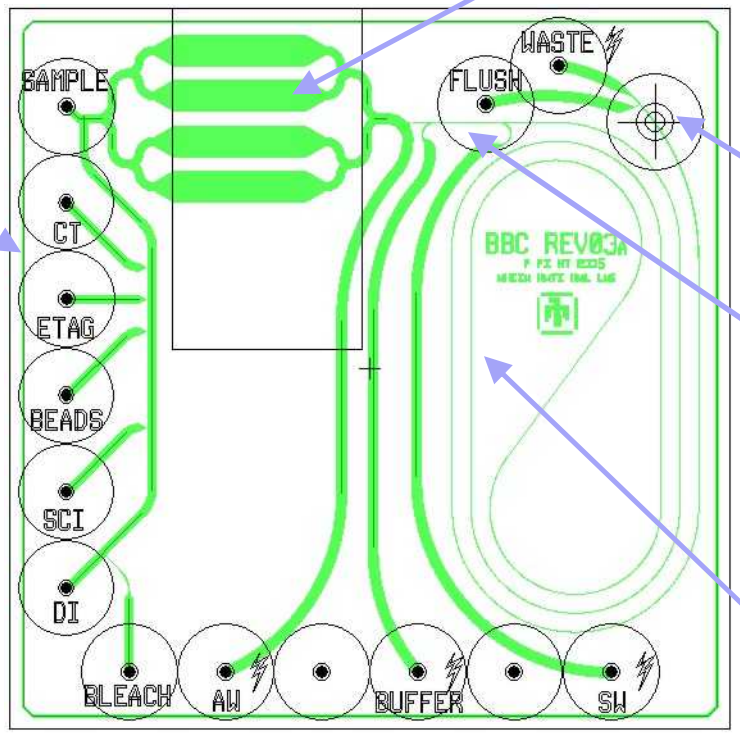
Microfluidic chip technology

- Design, Fabrication, and testing capabilities in a full range of materials:
  - Glass/Fused Silica
  - Plastic
  - Silicon
  - Ceramic

- Integrative components
  - Electrodes
  - Particle packed beds
  - Polymer structures
  - Mobile monolith (valves)

- Interfacing components
  - Manifolds
  - Fittings
  - Optics

Reagent inlet manifold

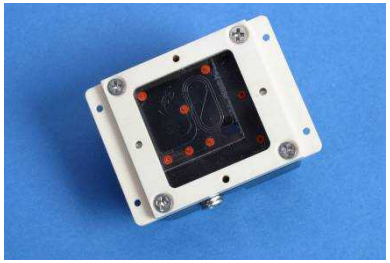


Magnetic Particle Trap

Optical Detection Point

500 nl Injection Tee

Separation Column 100 mm

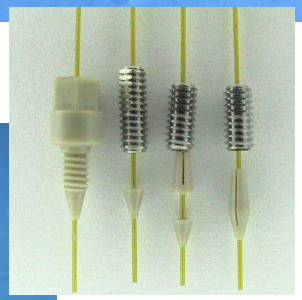


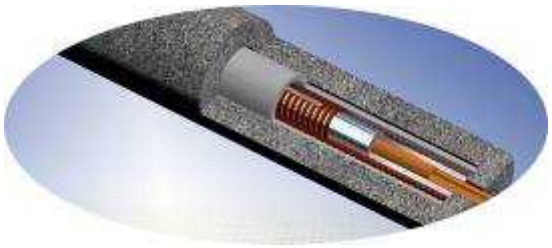
20 mm square

BioBriefcase Immunoassay chip

CapTite microfluidic fittings

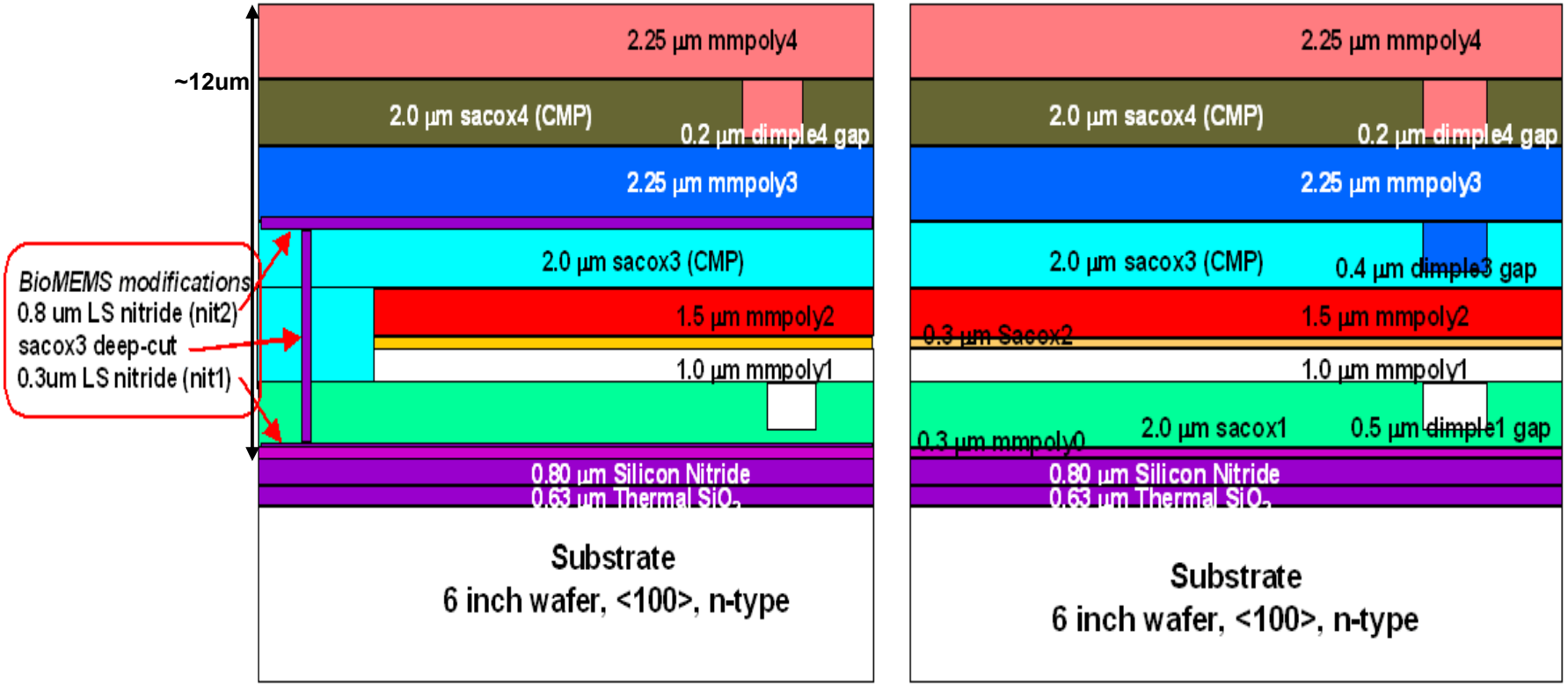
- Capillary Ferrule Fittings
- Chip-World Manifolds and fittings
- High-pressure Valves
- Reactors
- Thermal Cell Lysers





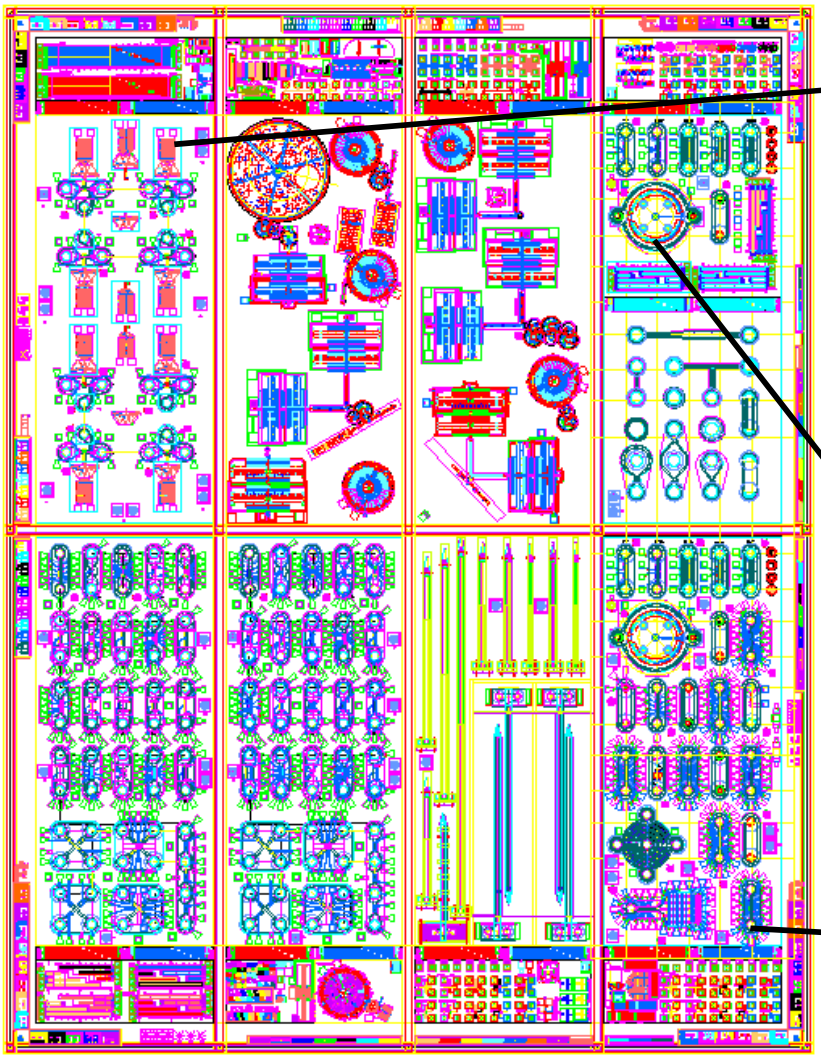
R. Renzi, 8724

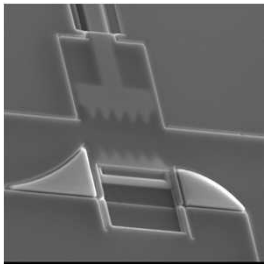
SwIFT™ and SUMMiT™

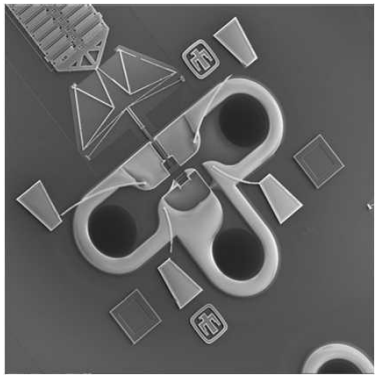


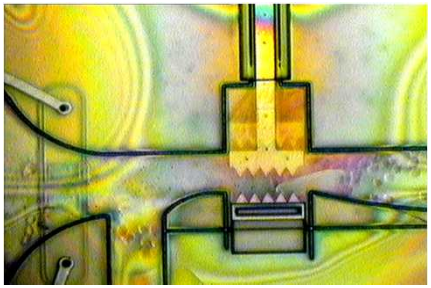
(a) SwIFT™ and (b) SUMMiT™ layers. The incorporation of the low stress silicon nitride layers allows the creation of complex microfluidic structures and enclosed cavities with optical access and provides the ability to create arbitrary fields inside these structures.

Devices in SwIFT™

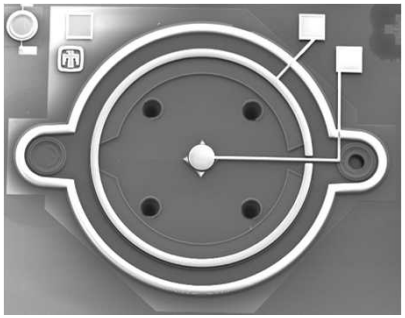




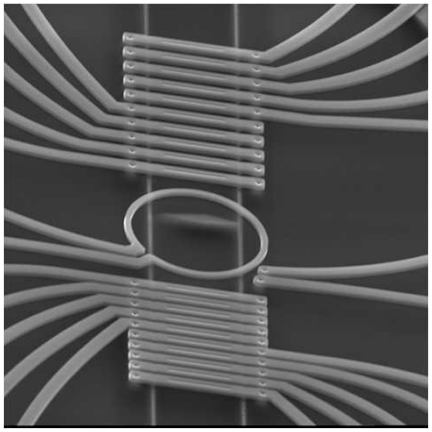




cellular manipulation

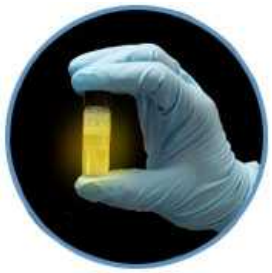


pumps



channels with electrodes

Potential Users: Who Needs It!?



"Challenges with current {*nanoparticle*} synthetic methods include the control of **defects**, **particle agglomeration**, **inhomogeneities** of composition and size distribution, and the lack of cost-effective, controllable synthetic methods amenable to **scale-up**."

- Roadmap for Nanomaterials

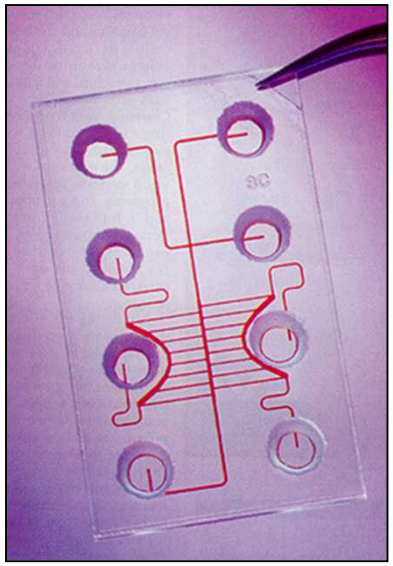
Key Science Functions...

<u>Synthetic Chemistry Kinetics</u>
- Molecular precursors
- Nanoparticles
- Catalyst Activity
- Colloidal Assembly

Overlap with other Discovery Platforms

Biological Reactions/Response

Chemical synthesis for Biomedicine

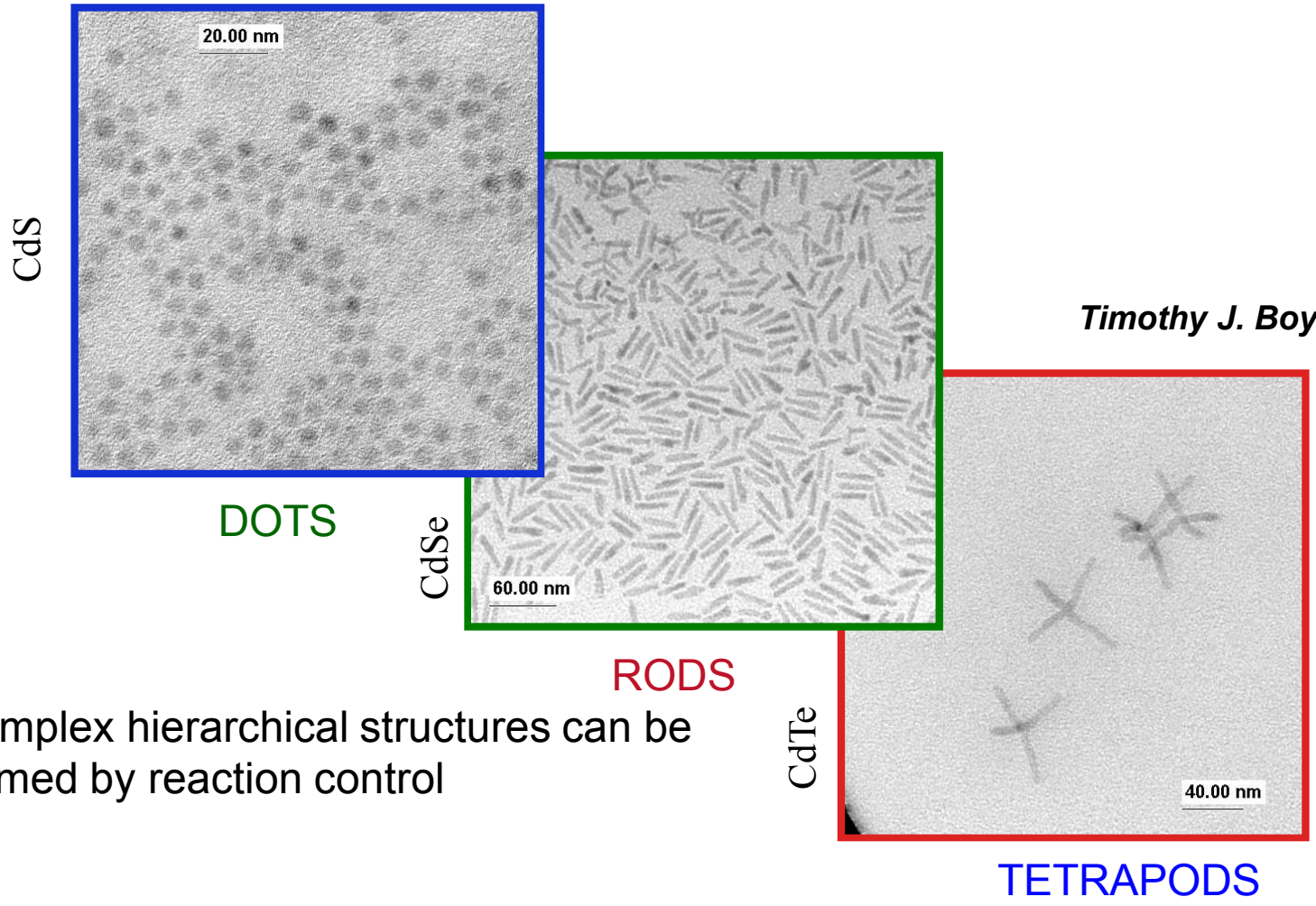


Controlled Environment
- Flow Control (laminar, electroosmosis
- Thermal Control – high heat transfer rates, low Cp
- Mass Transport Control

Reactor Control
- Fundamental Chemistry Studies
- Modeling (geometry, laminar flow)

Microfluidic Synthesis - Motivation

Phase stability and morphology of nanoparticles is thermally and compositionally controlled

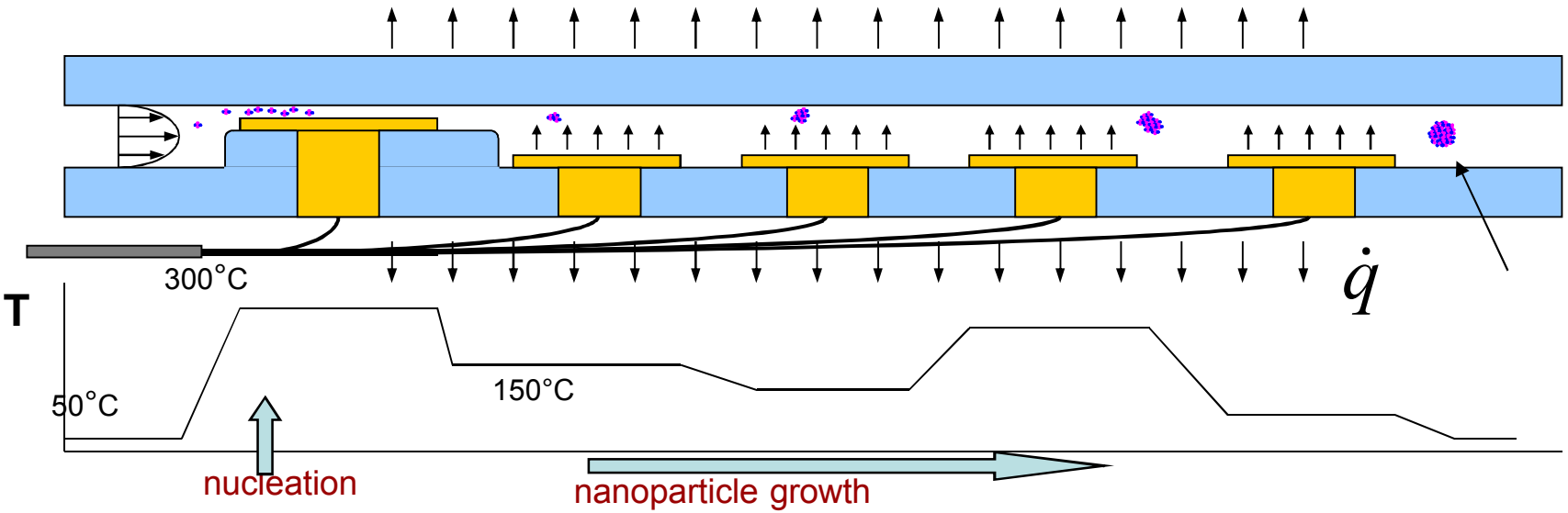


Timothy J. Boyle, Sandia

Complex hierarchical structures can be formed by reaction control

Microfluidic Synthesis Discovery Platform:

Understanding the Kinetics of Nanomaterial Synthesis

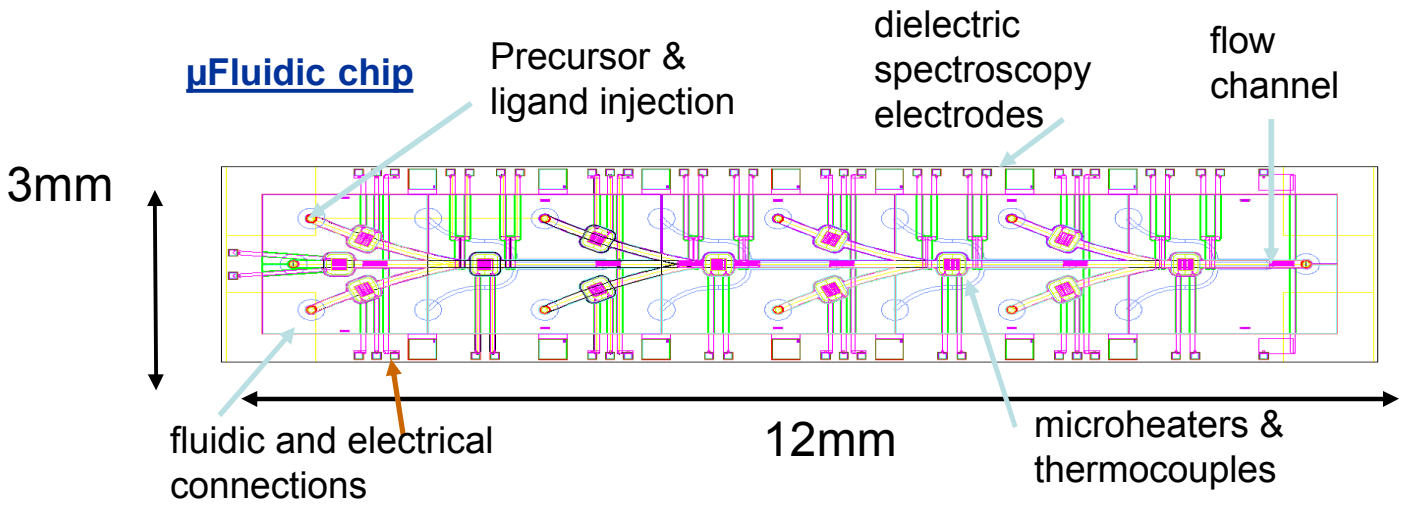


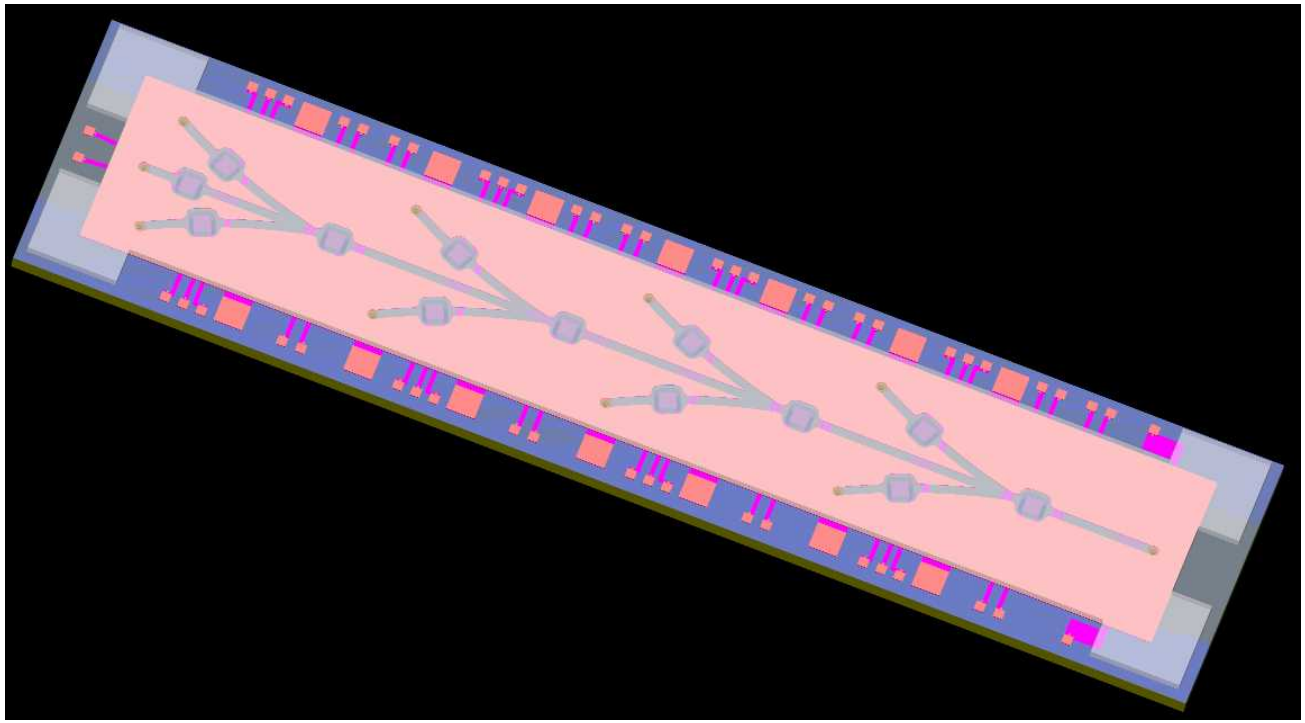
Development of a basic understanding is needed for future "continuous flow" reactors.
Control of thermal profile allows fundamental studies of synthesis reactions.

- What are the values of the thermodynamic parameters that control nanoparticle synthesis? (enthalpy, entropy, surface energy)
- What is the mechanism of nanoparticle nucleation and growth? (i.e. diffusion, surface reaction, self-assembly)
- What is the mechanism of the formation of shell layers around a core nanoparticle?
- How does the surfactant composition relate to the quantum confinement properties of nanoparticles?

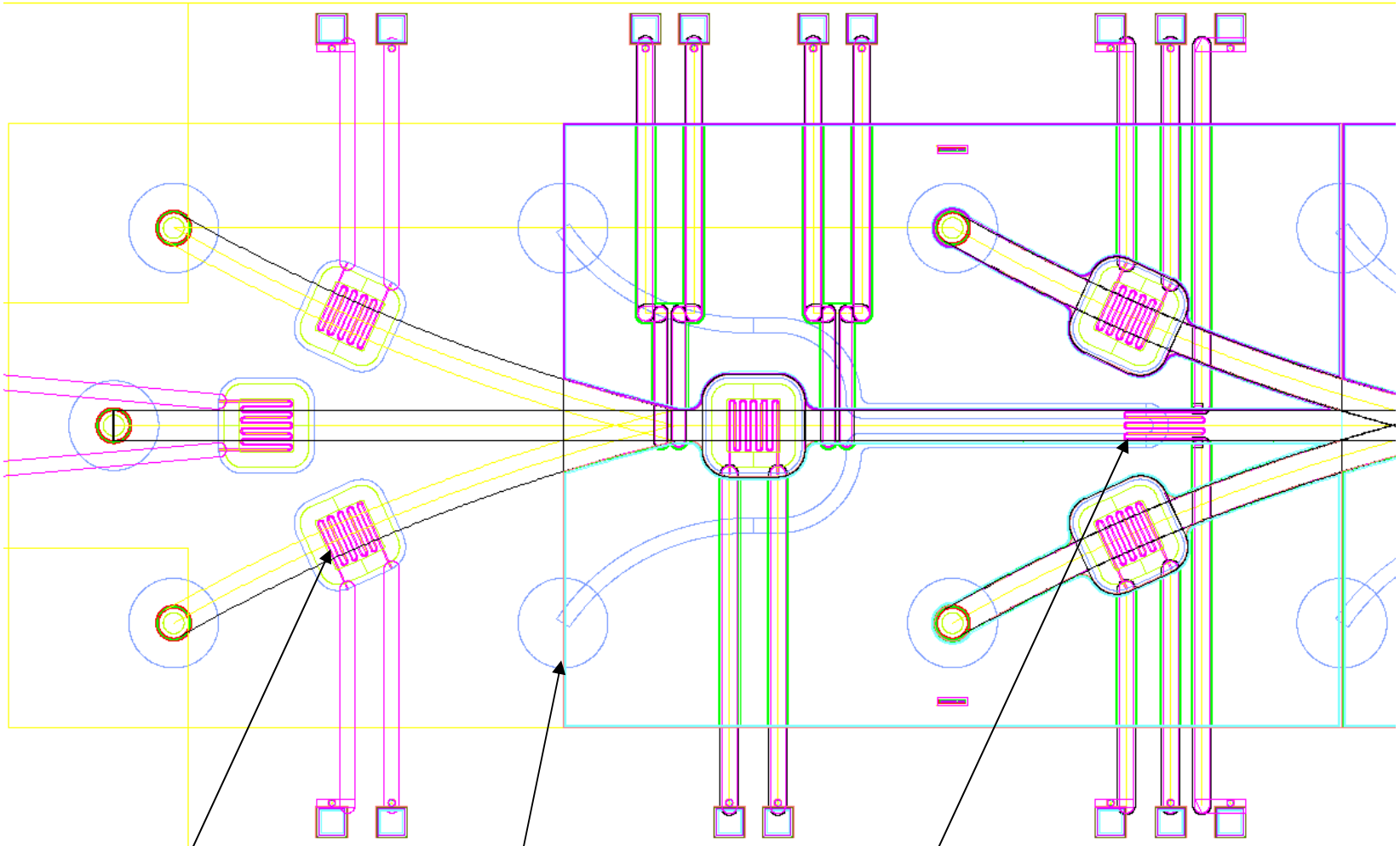
- Microfluidic chip will be integrated within a carrier platform
- A SWIFT-lite process will be used to develop the heater and sensor elements.
- Users include synthetic chemists, quantum dot material synthesis.

Microfluidic Synthesis Platform - Design





Microfluidic Platform – Entry Stage

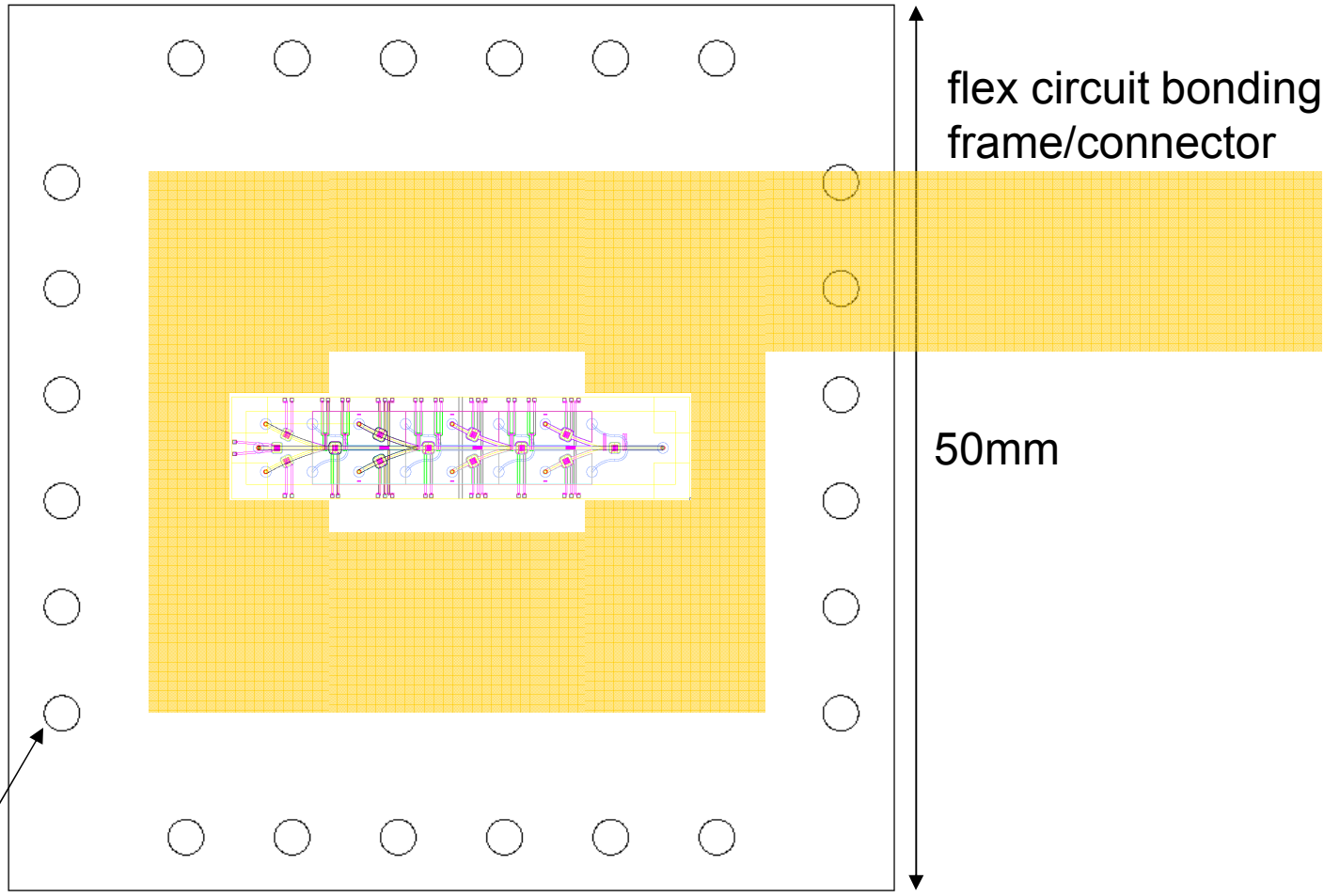


isolated resistors for high temp.

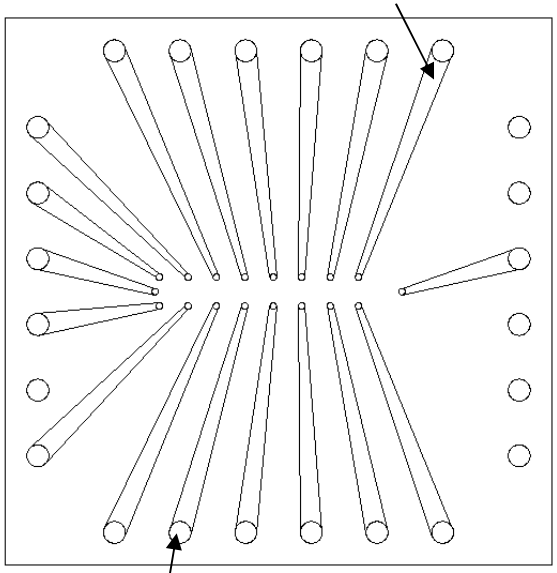
channels for temp. control in silicon bulk

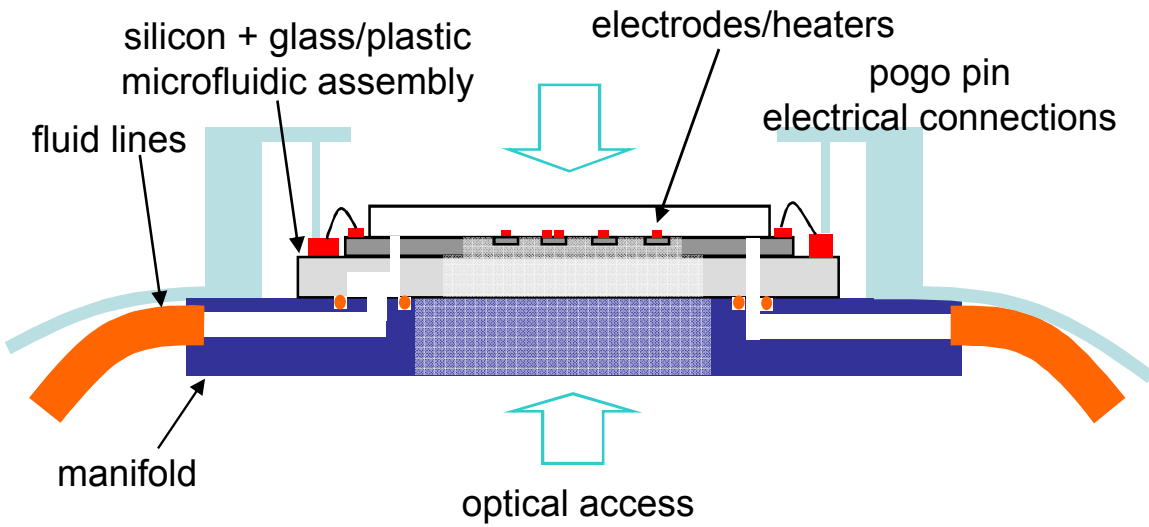
non-isolated resistors for temp. measurement/control

Microfluidic Platform

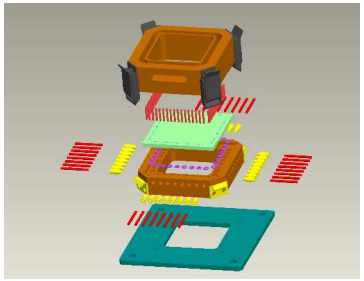


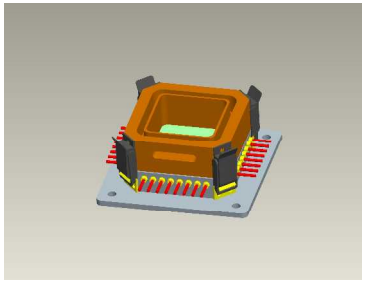
Microfluidic Platform – fanout and manifold connections





The cover and fan out glass must be anodically bonded to the Microfluidic Synthesis DP.





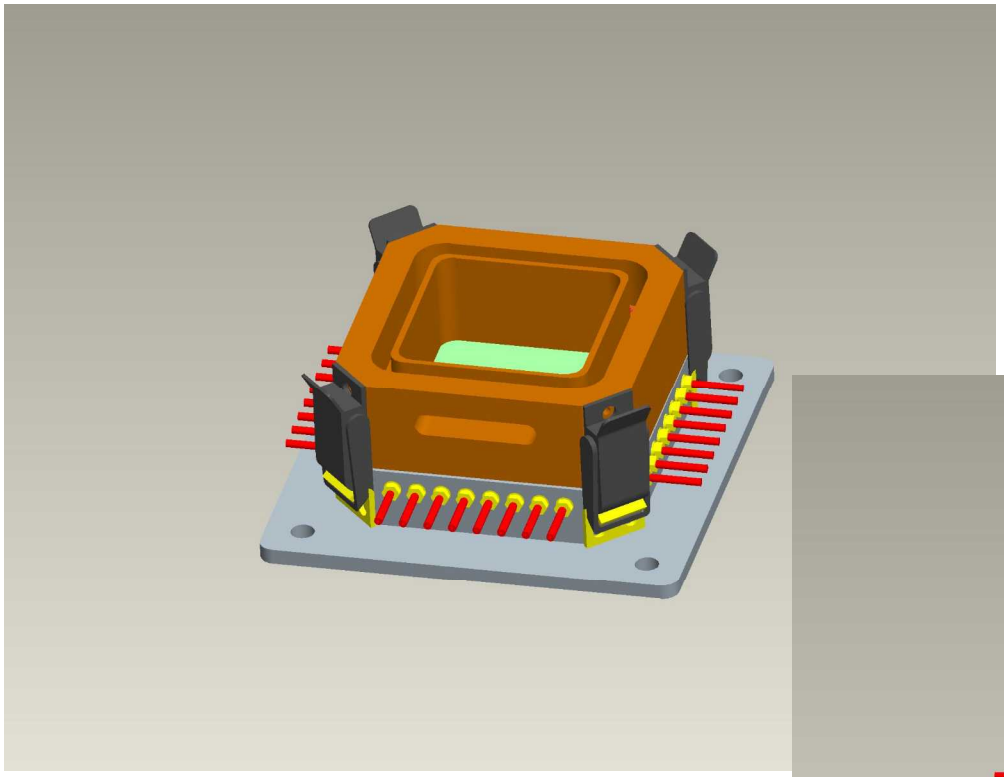
Integration package

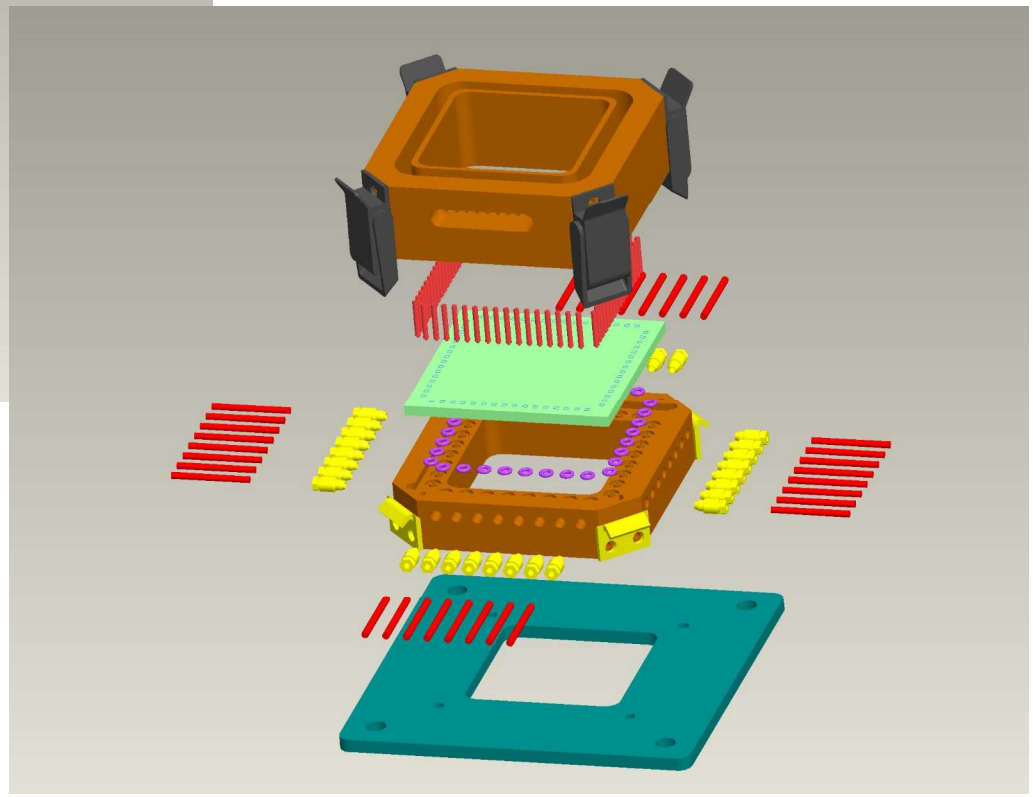
- 64 pogo-pin connections utilizing one common interface connector
- 32 fluidic connections
- 1.5 inch square top/bottom access

- O-ring seals to 500 psi
- Dowel pin alignment
- 4-place draw-latch compression

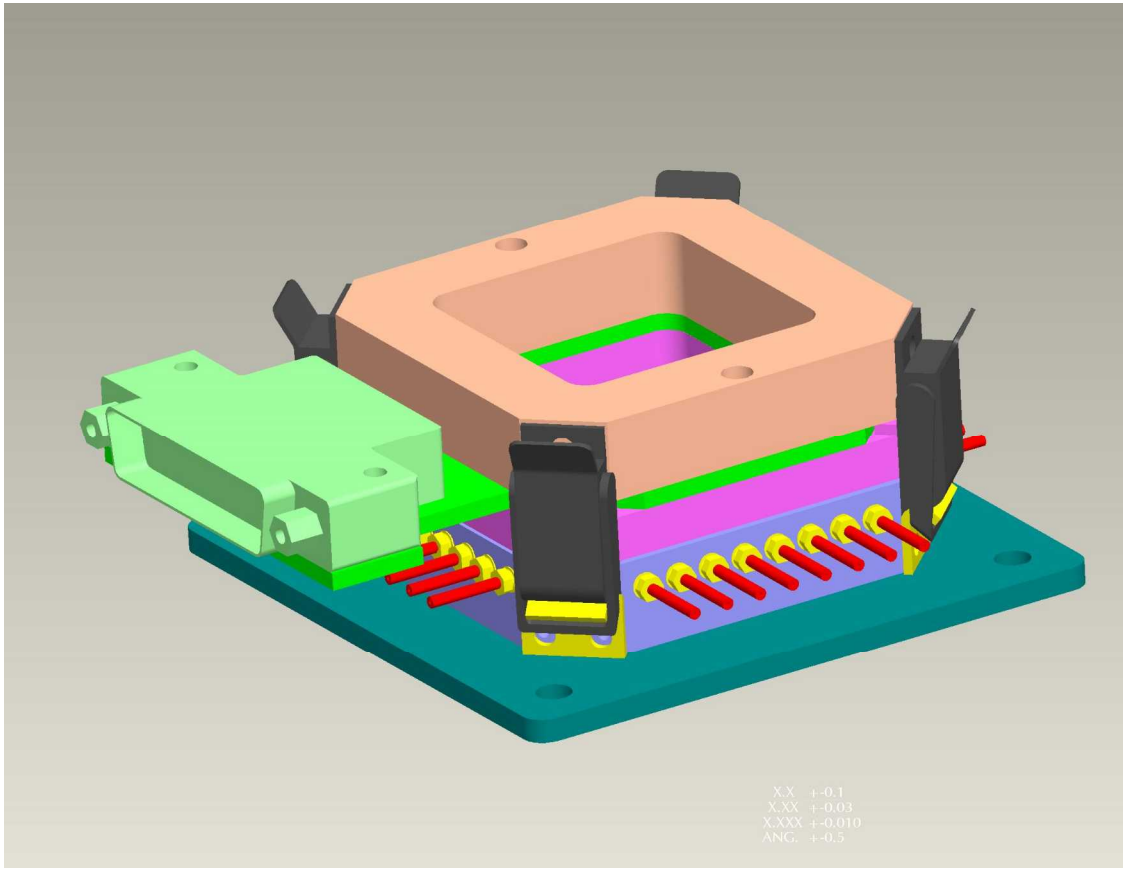
- Circuit board connections soldered directly to pogo-pins
- MDM connector for reliable
- assembly and disassembly

Microfluidic Platform (manifold – Ron Renzi, SNL/CA)





CINT Discovery Manifold with Integrated Connector



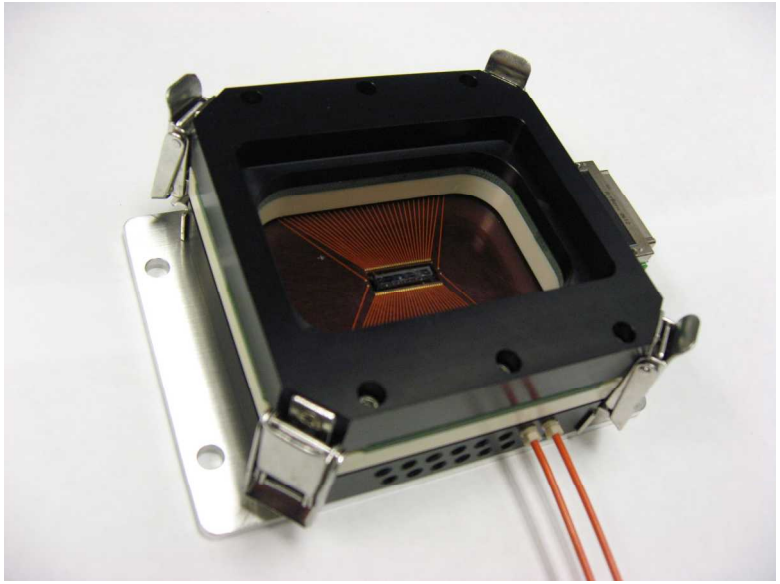
Specifications:

- 64 pogo-pin connections utilizing one common interface connector
- 32 fluidic connections
- 1.5 inch square top/bottom access
- O-ring seals to 500 psi
- Dowel pin alignment
- 4-place draw-latch compression
- Circuit board connections soldered directly to pogo-pins
- MDM connector for reliable assembly and disassembly

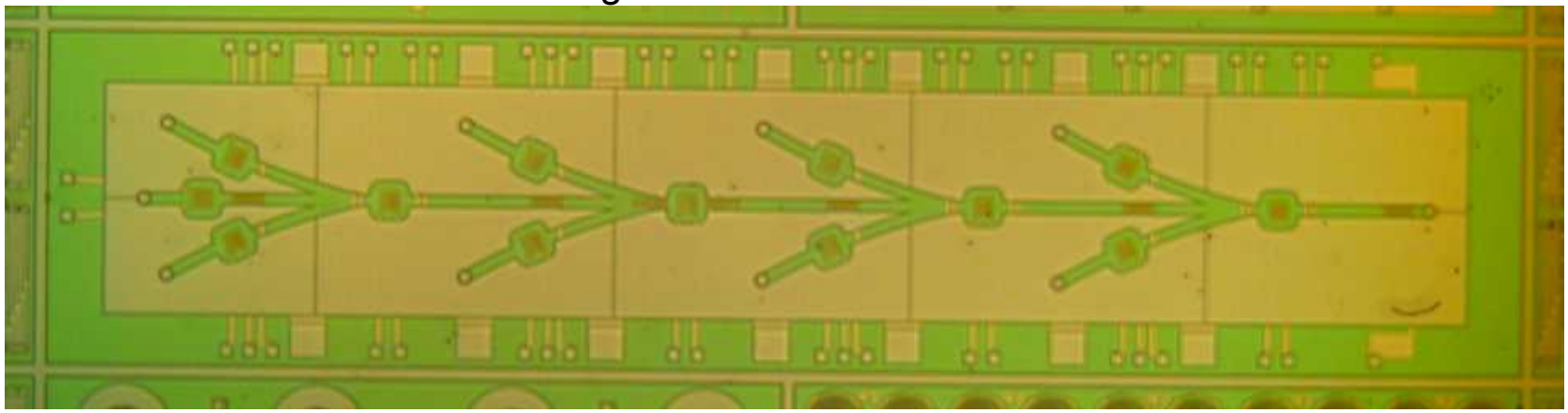
Approximate Size: 2.5” x 3.5” x 1.25”

R.F.Renzi 11/08/05

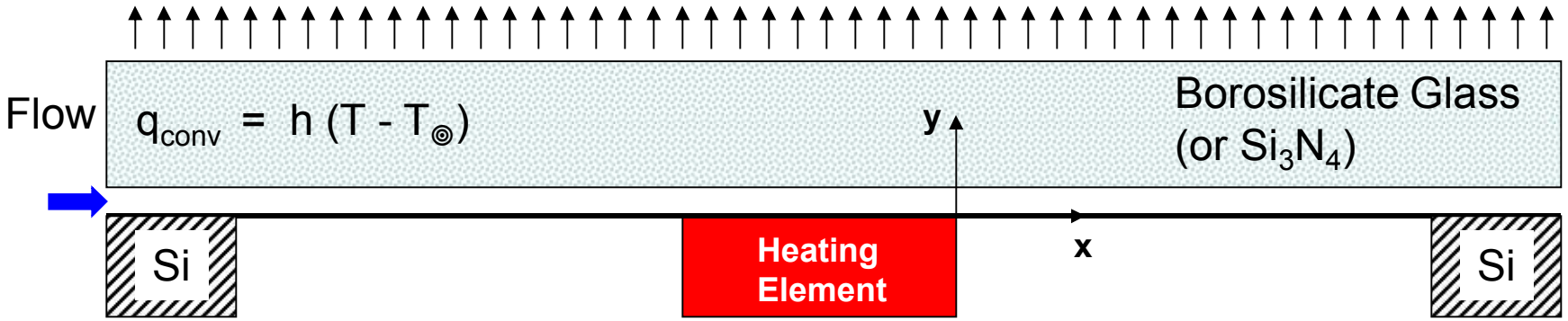
Microfluidic Platform –Manifold and Manufactured Network

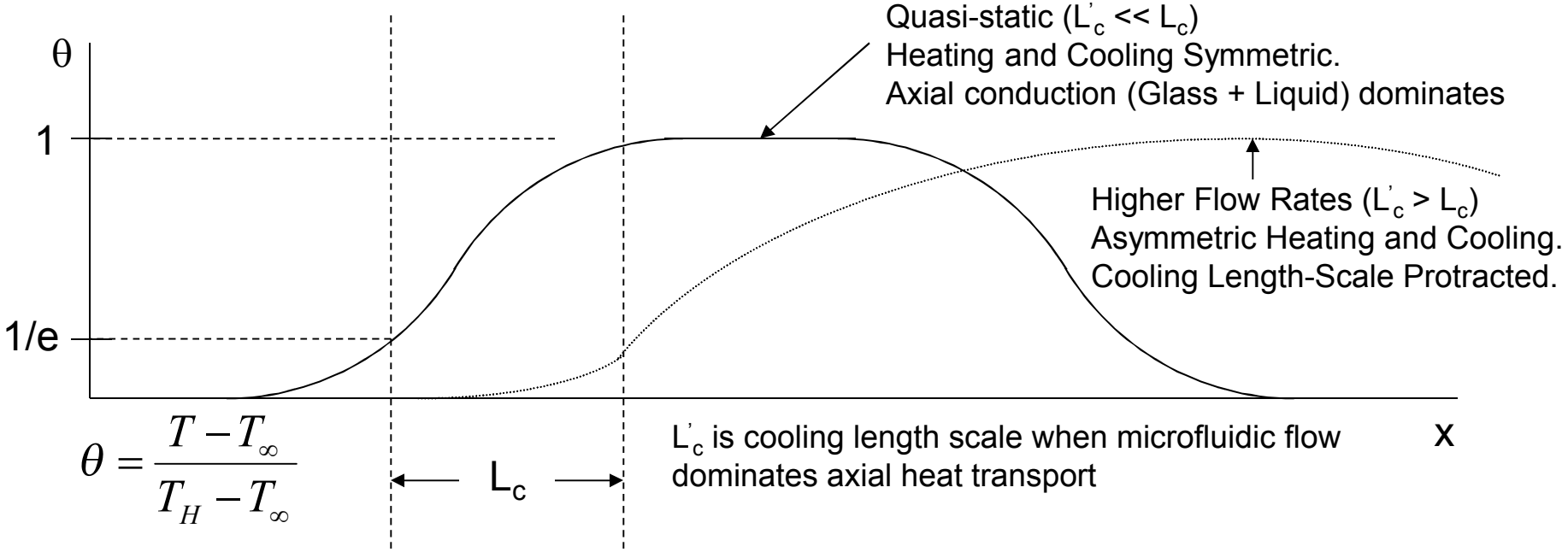


Microfluidic Network before dicing and release from the wafer.



Axial Temperature Profile Modeling

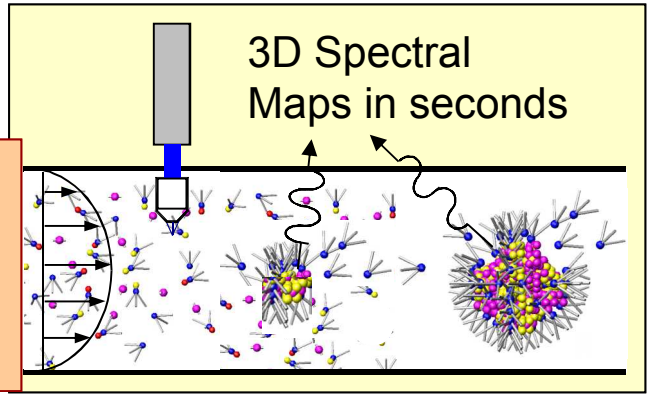




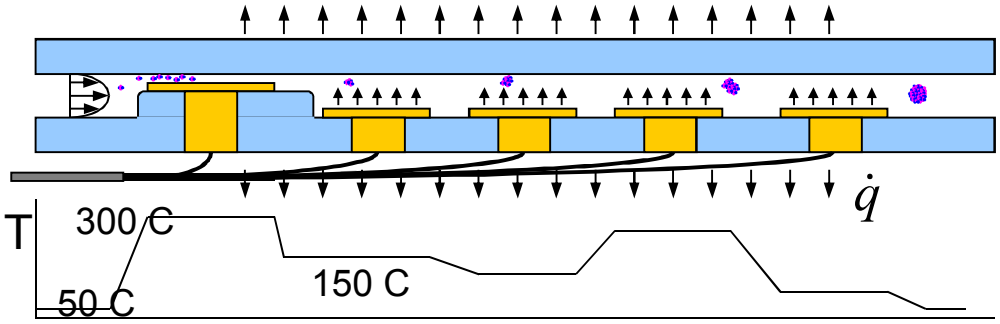
Future Directions

Improved Optical Diagnostics:

3D Hyperspectral Scanner
- Sub-μm resolution
- Single-dot sensitive
- 3D scanning



- Advanced Microfabrication: local temperature control, mixing, etc.



- Other Chemistries and Materials

Types of Studies

- “magic number” synthesis
- optical effects during synthesis
- reaction kinetics
- growth and dissolution
- heteronucleation of shell structures
- shape control
- non-congruency in growth
- ligand effects