Why do Carbon Nanotube Synthesis Using The Jefferson Lab Free Electron Laser?

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From “If It’s Nano, It’s Big”
--Washington Post, Feb. 23, 2004

“Overall, success in the laboratory has been remarkably difficult to translate into real world products.”

“…venture capital is fueling less than 10 percent of nanotech, and many venture firms won’t touch it until the industry demonstrates that it can efficiently bring real products to market.”

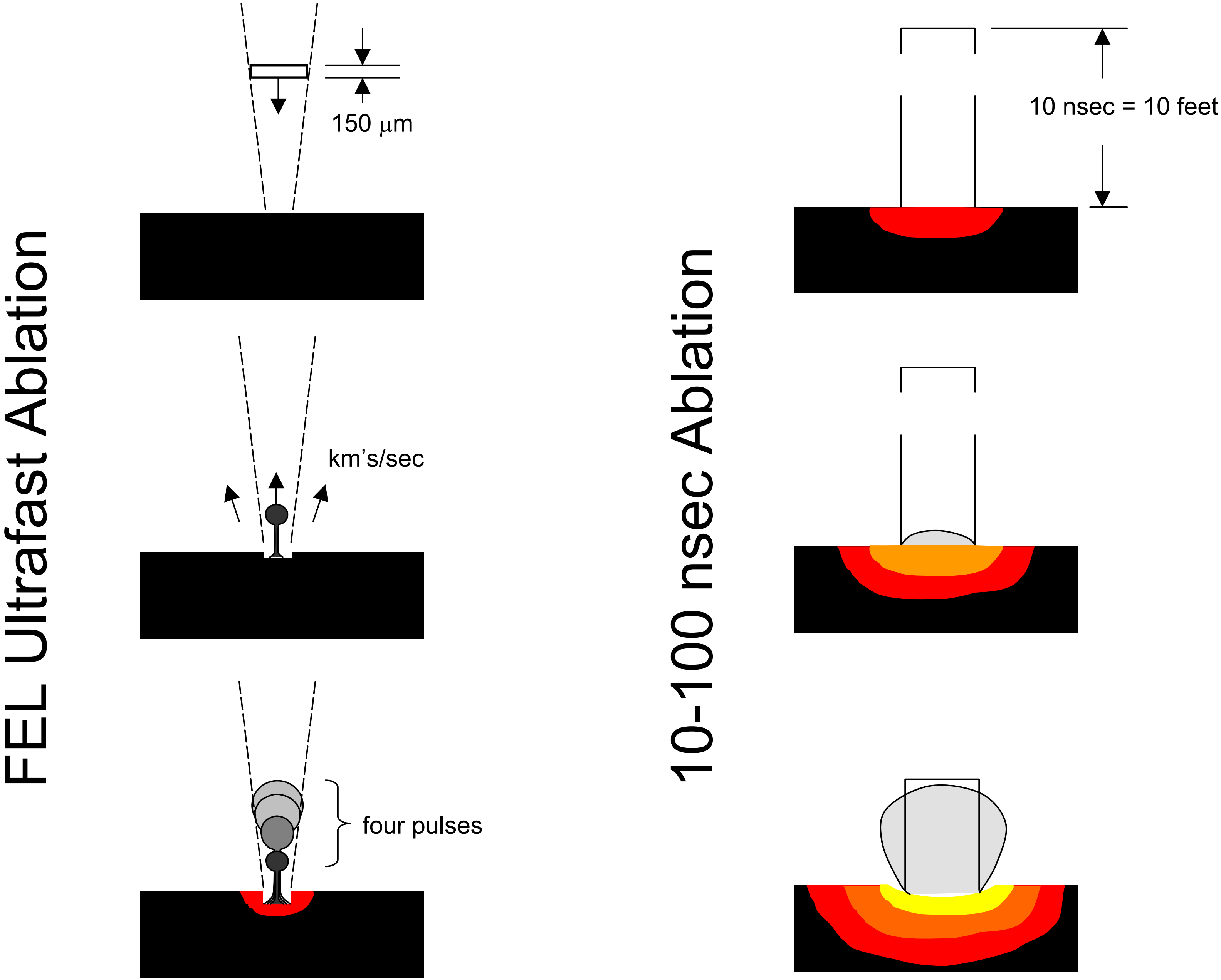

www.bsmotoring.com
Photo: Ferrari
Marlboro
vodafone
vodafone

Why are we here?…

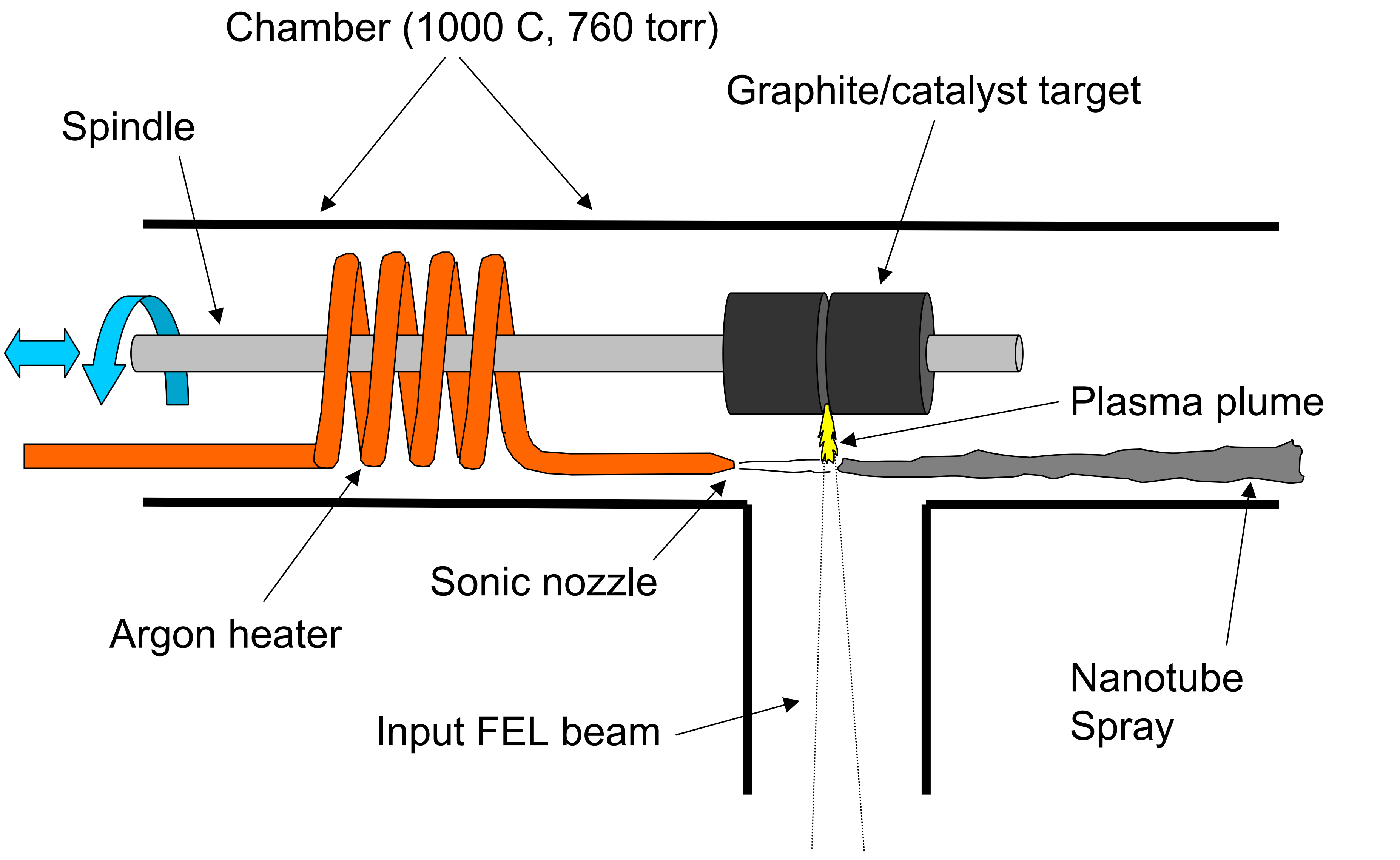
The nanotube supply problem has NOT been solved!

Desirable Nanotube Properties for Fiber-Reinforced Composites

- Single wall.
- Long.
- High Quality (straight walls).
- Pure/Purifiable.
- Dispersable.
- Specific Chirality (conduction and sensing).

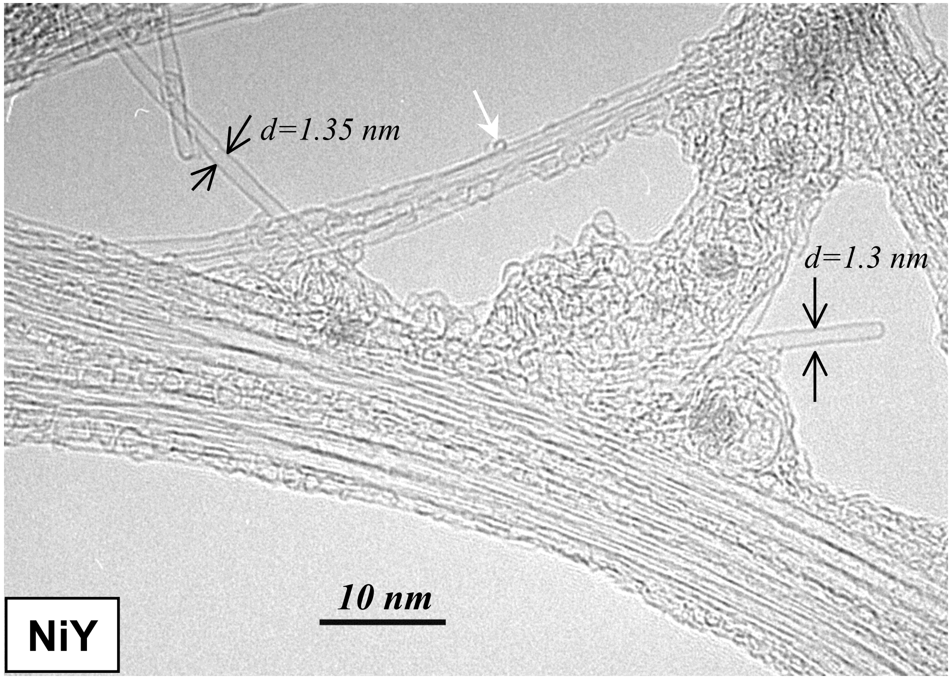

FEL Ultrafast Ablation
150 μm
km's/sec
four pulses
10-100 nsec Ablation
10 nsec = 10 feet

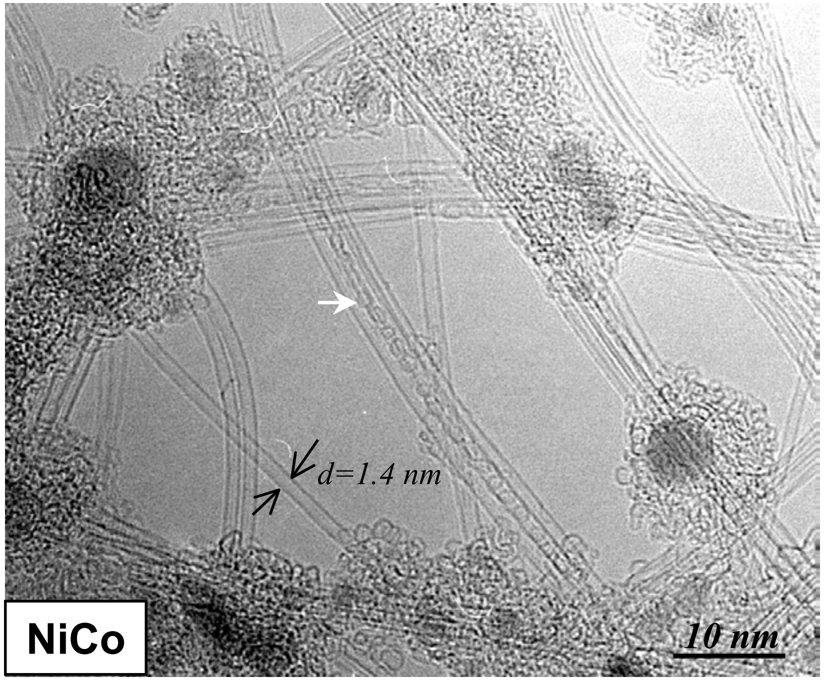
Schematic of First Side-Pumped Synthesis Chamber



New and Used Target from Side-Pumped Chamber

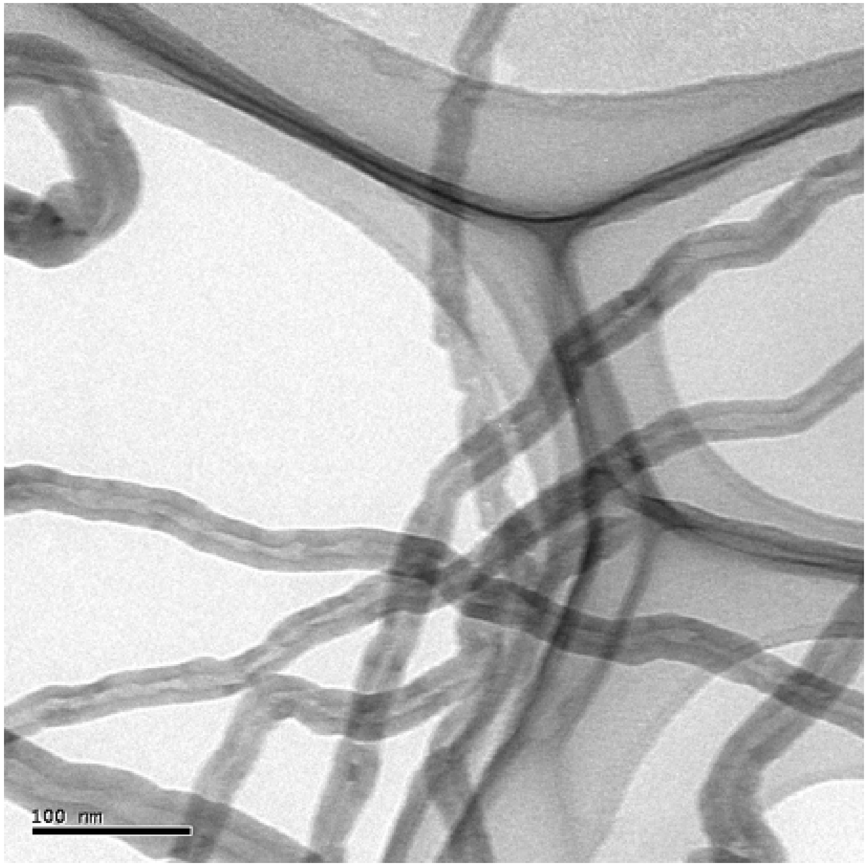
High Resolution TEM Shows Small Bundles and Individual Tubes





- No double-wall or multi-wall tubes are seen
- Straight walls are indicative of low defect composition.

“Low Quality” Nanotubes (bulk Chinese product)



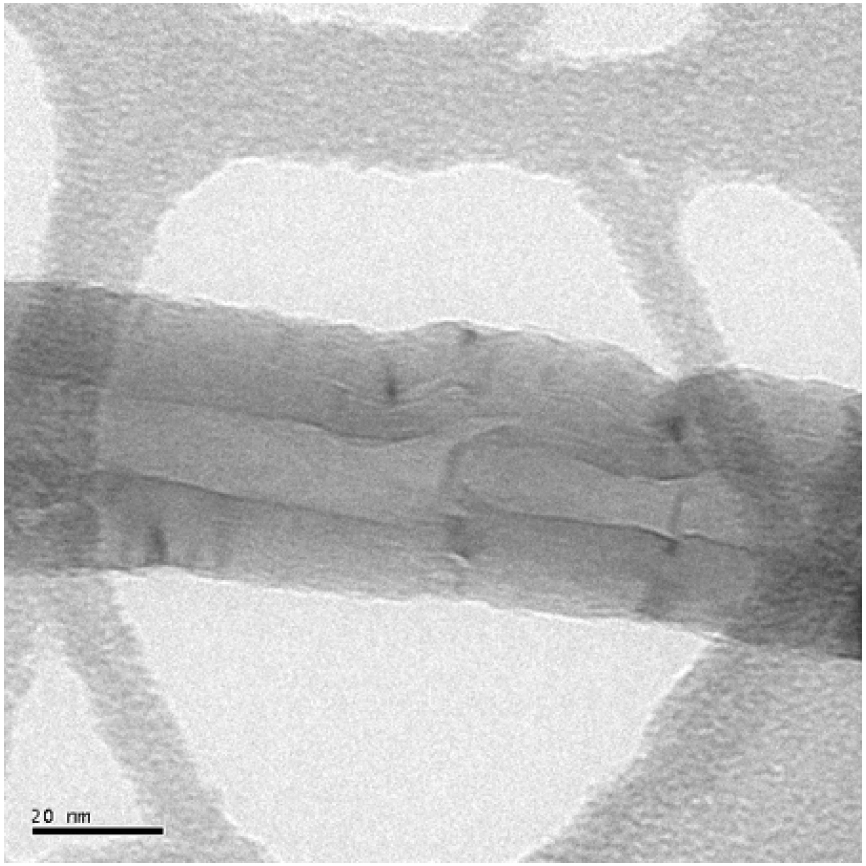
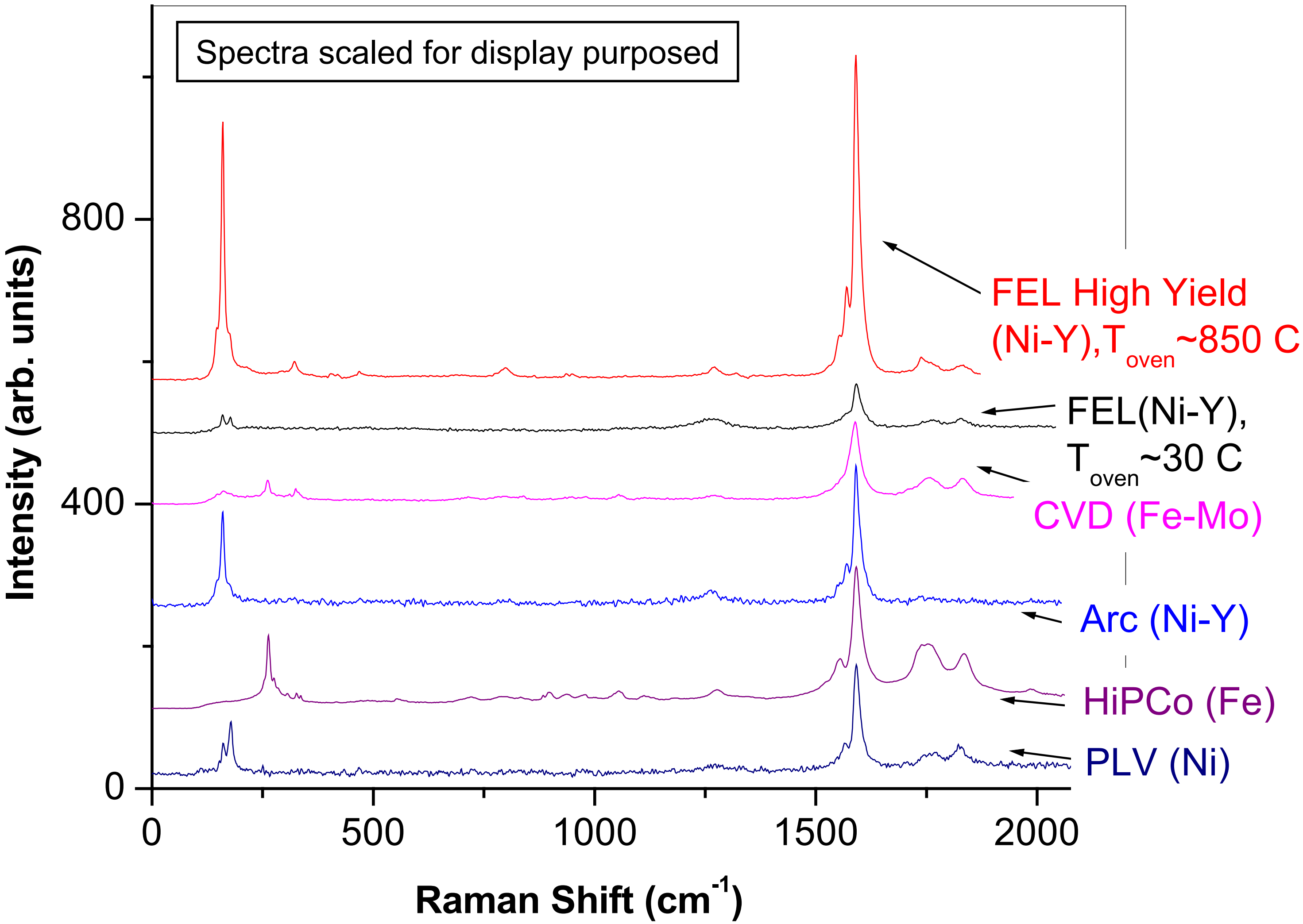


Image Credits: Dr. Roy Crooks (Swales/NASA LaRC),
Contributed via Cheol Park (NIA/NASA LaRC)

Raman Spectroscopy Of FEL tubes vs other synthesis techniques

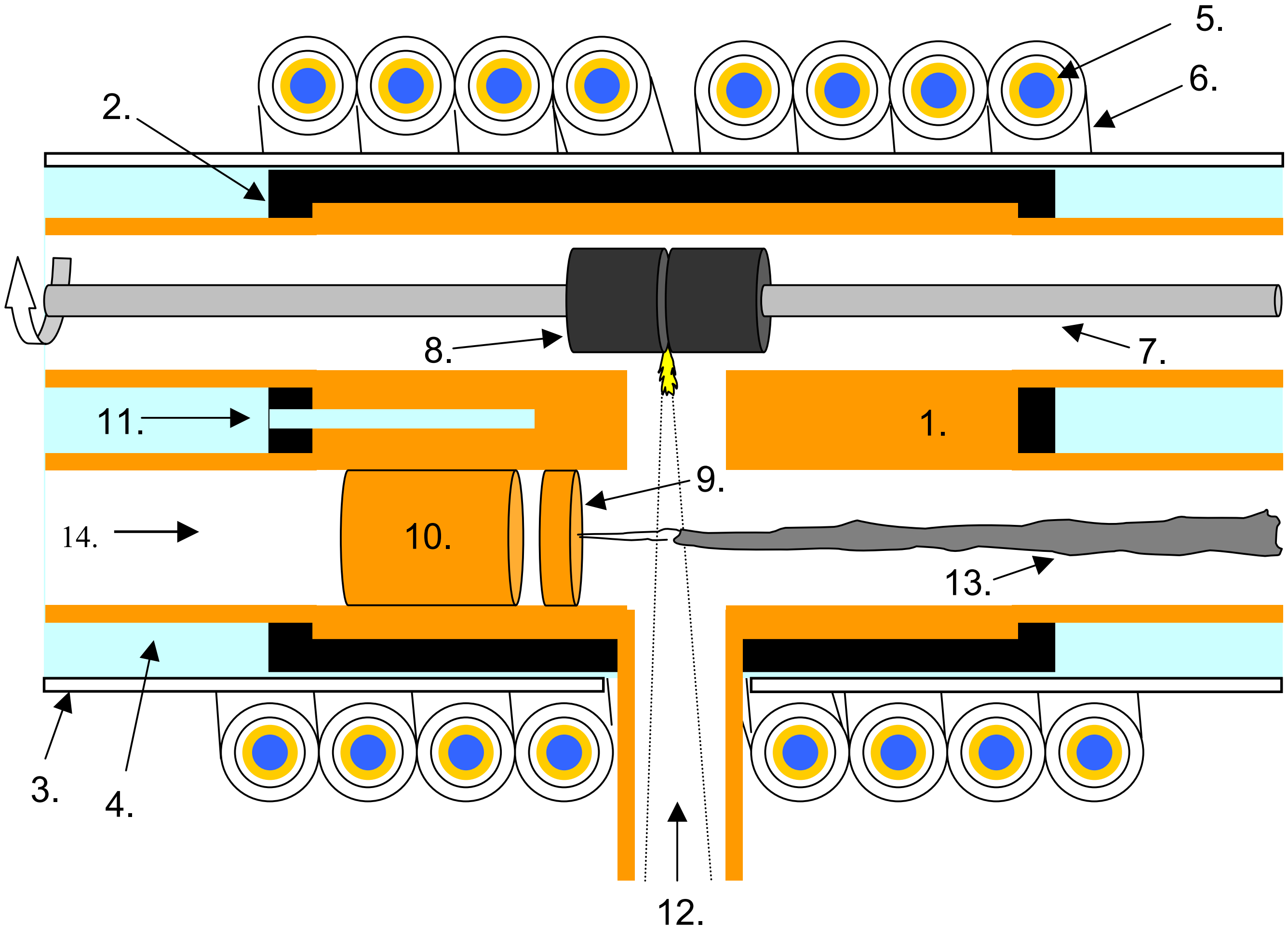


Achievements, 1 kW Demo Runs

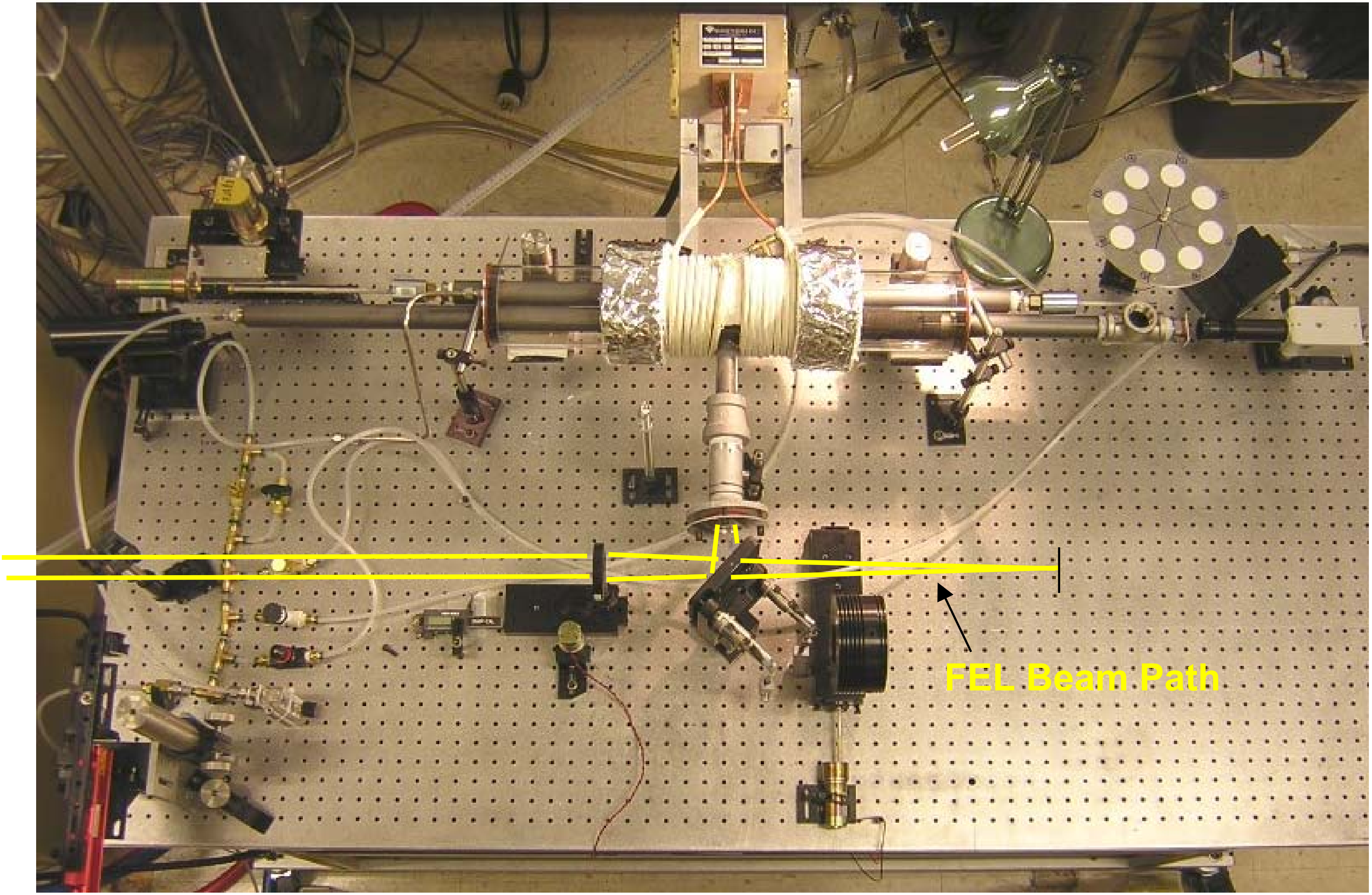
- 2 g/hour SWNT raw material production rate (10 g/hour ablation rate).
- Low defect morphology.
- Small bundles.
- Parametric science:
  - Synthesis at 1, 3, 5, and 6 microns (3 microns worked)
  - Discovered plume/beam interaction (axially-pumped rig)
  - Showed target speed (dwell) is critical to ablating in ultrafast mode.
  - Showed ambient heating is still required, even for highly energetic plume.
  - Showed ambient pressure not critical over .5 to 1 atm. range.

The New Production/Research Device:

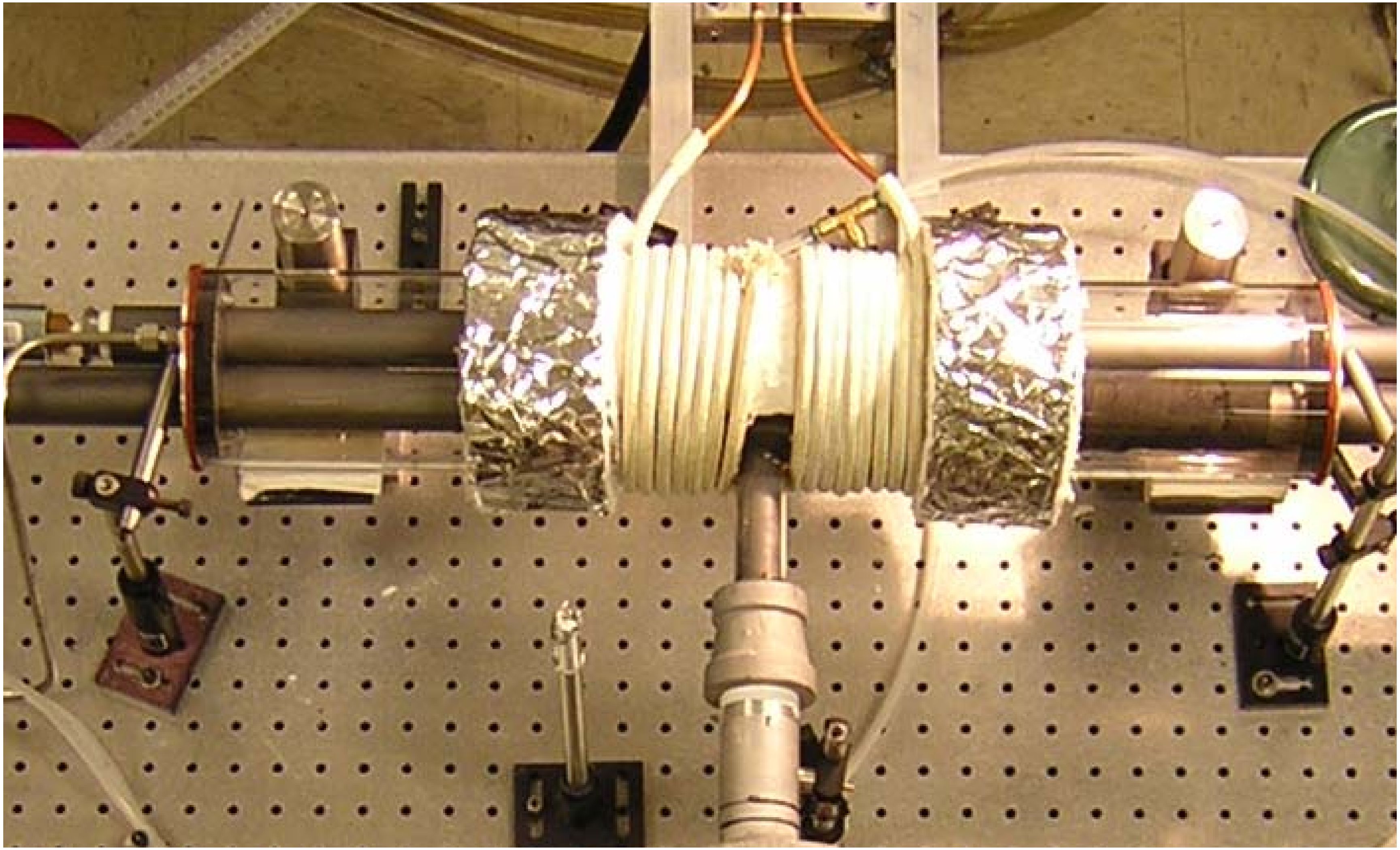
Induction-Heated Side-Pumped SWNT Synthesis Chamber



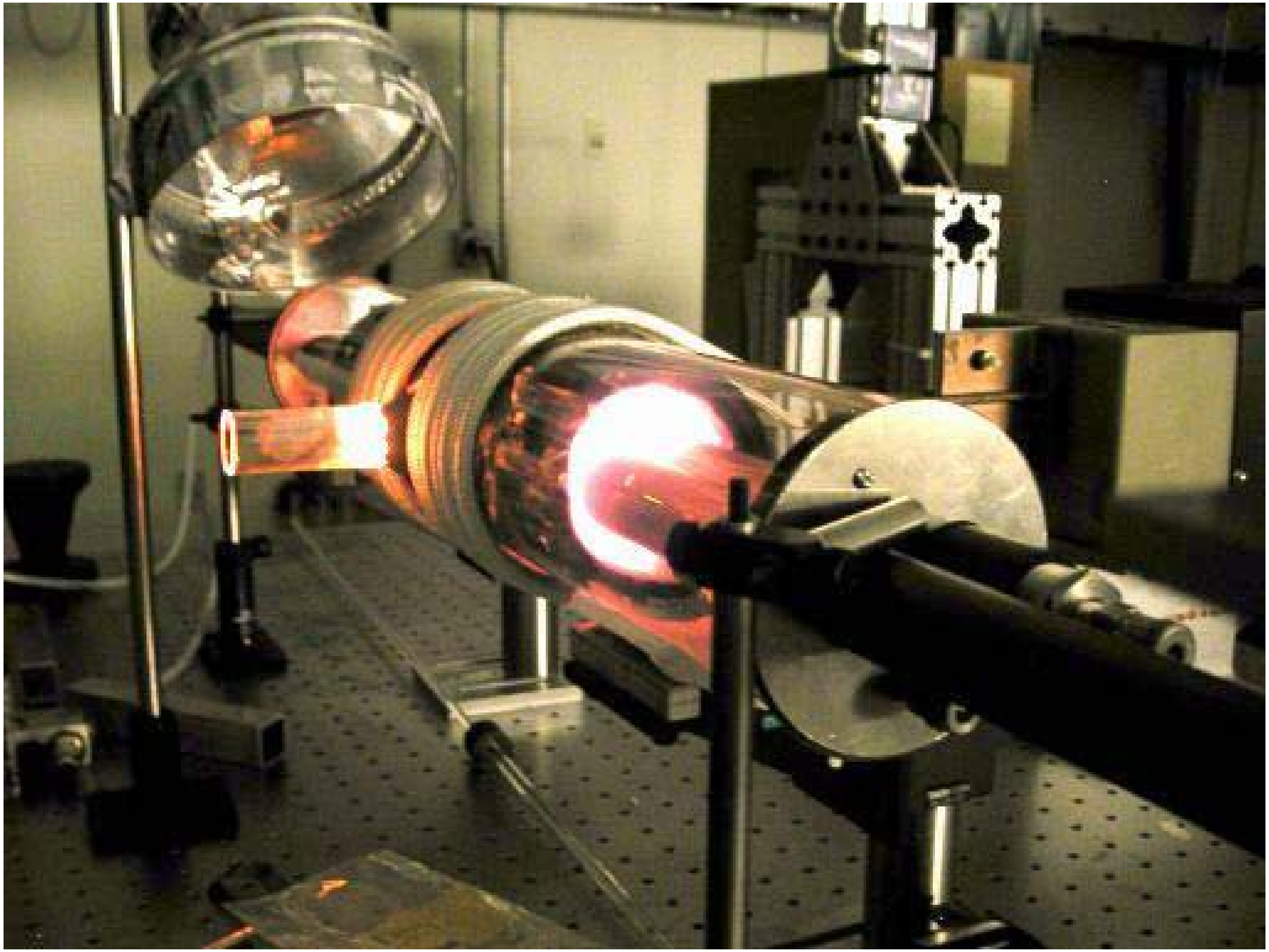
Apparatus, Overhead View



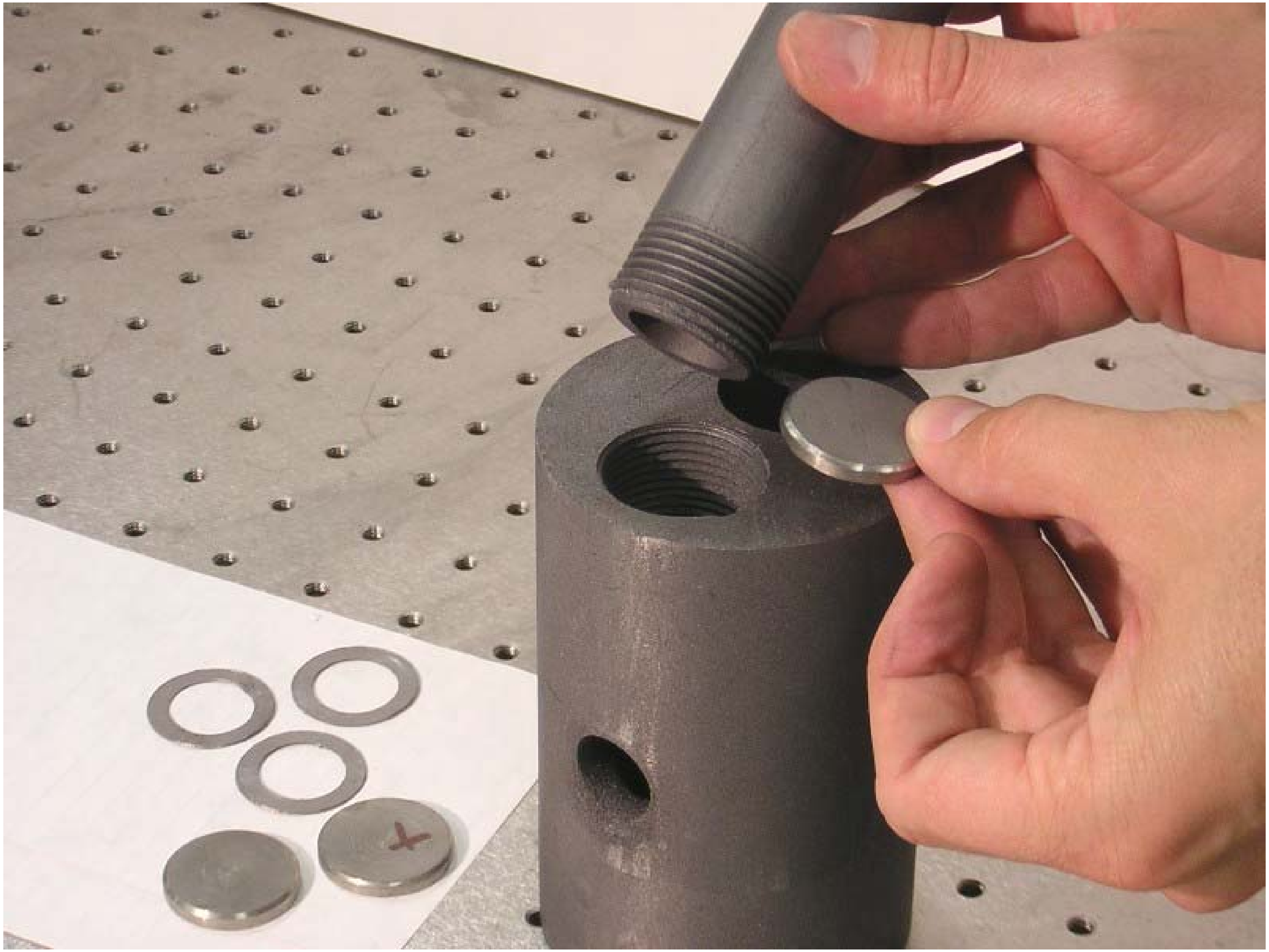
Chamber, Hot Zone



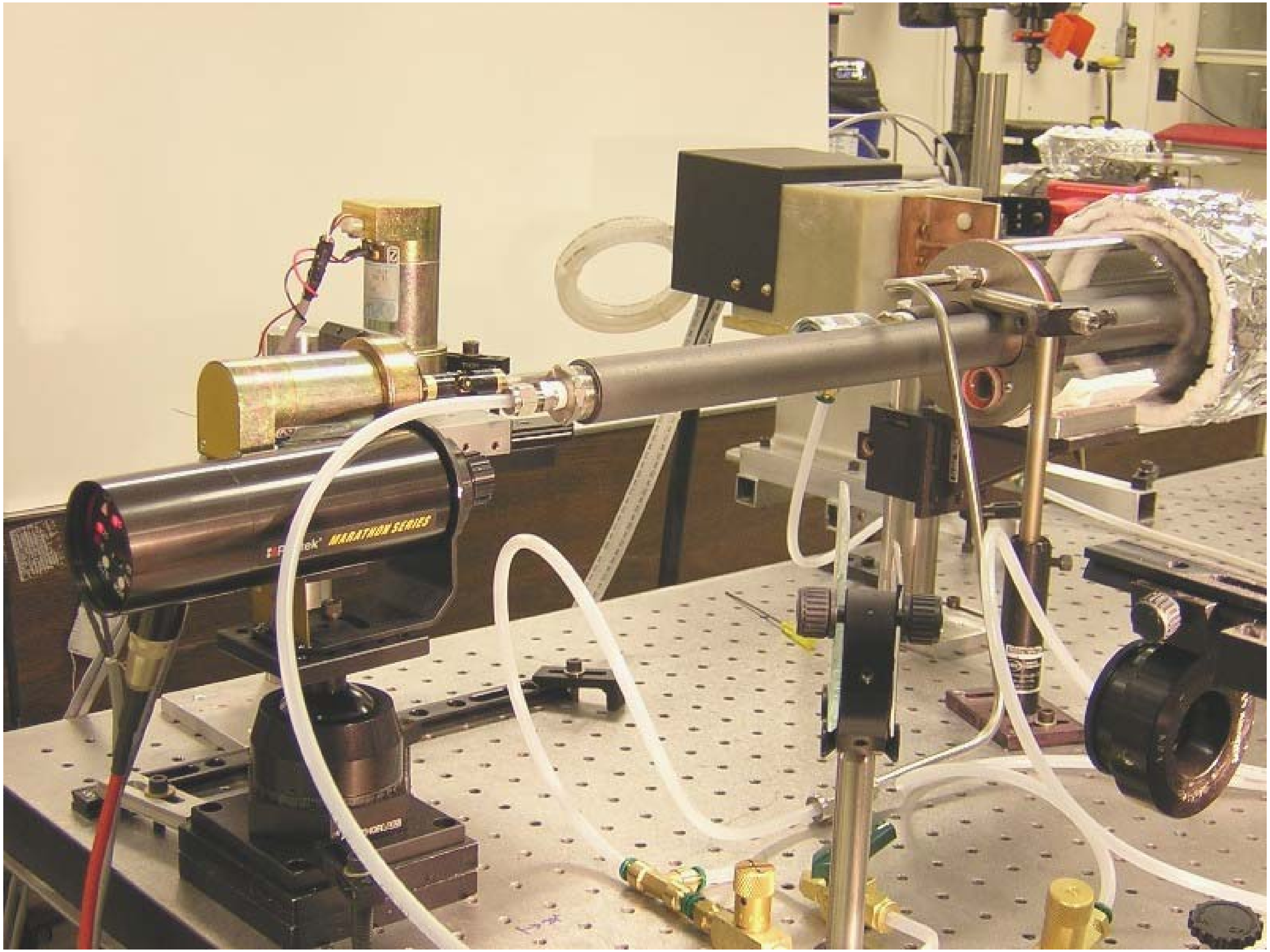
Heating Test, Prototype Chamber



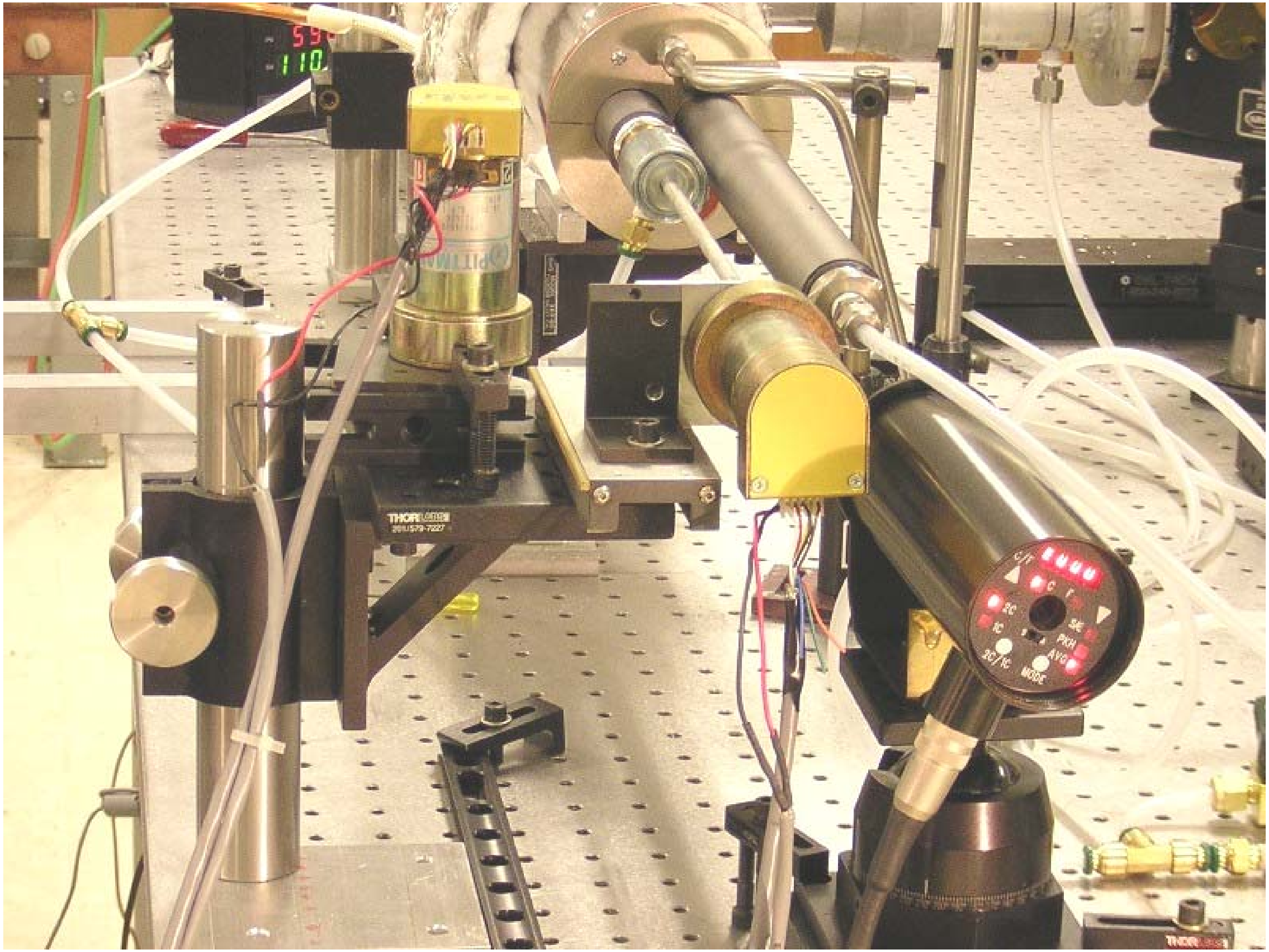
Chamber Core with Orifice Plate



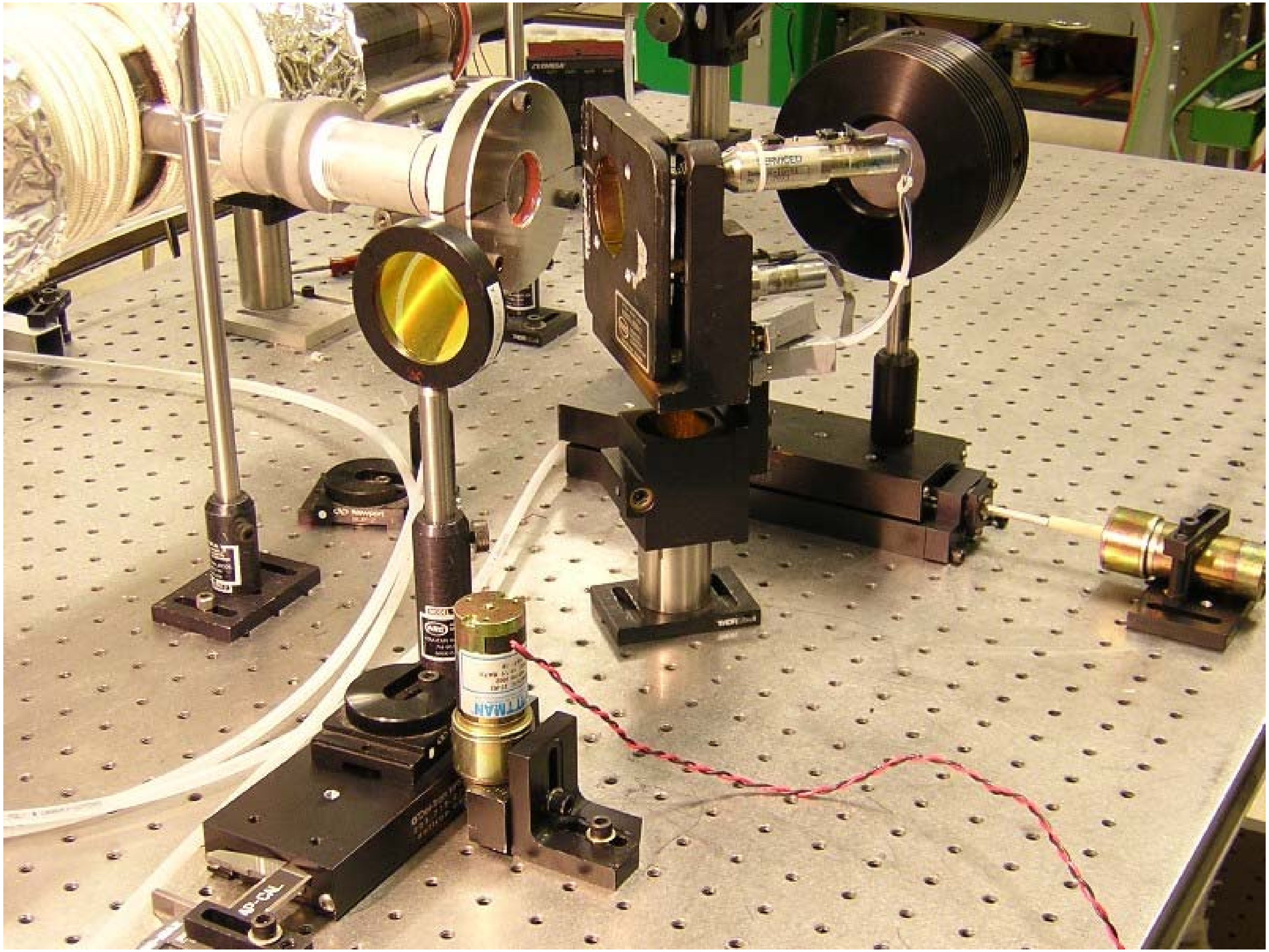
Chamber, Upstream End



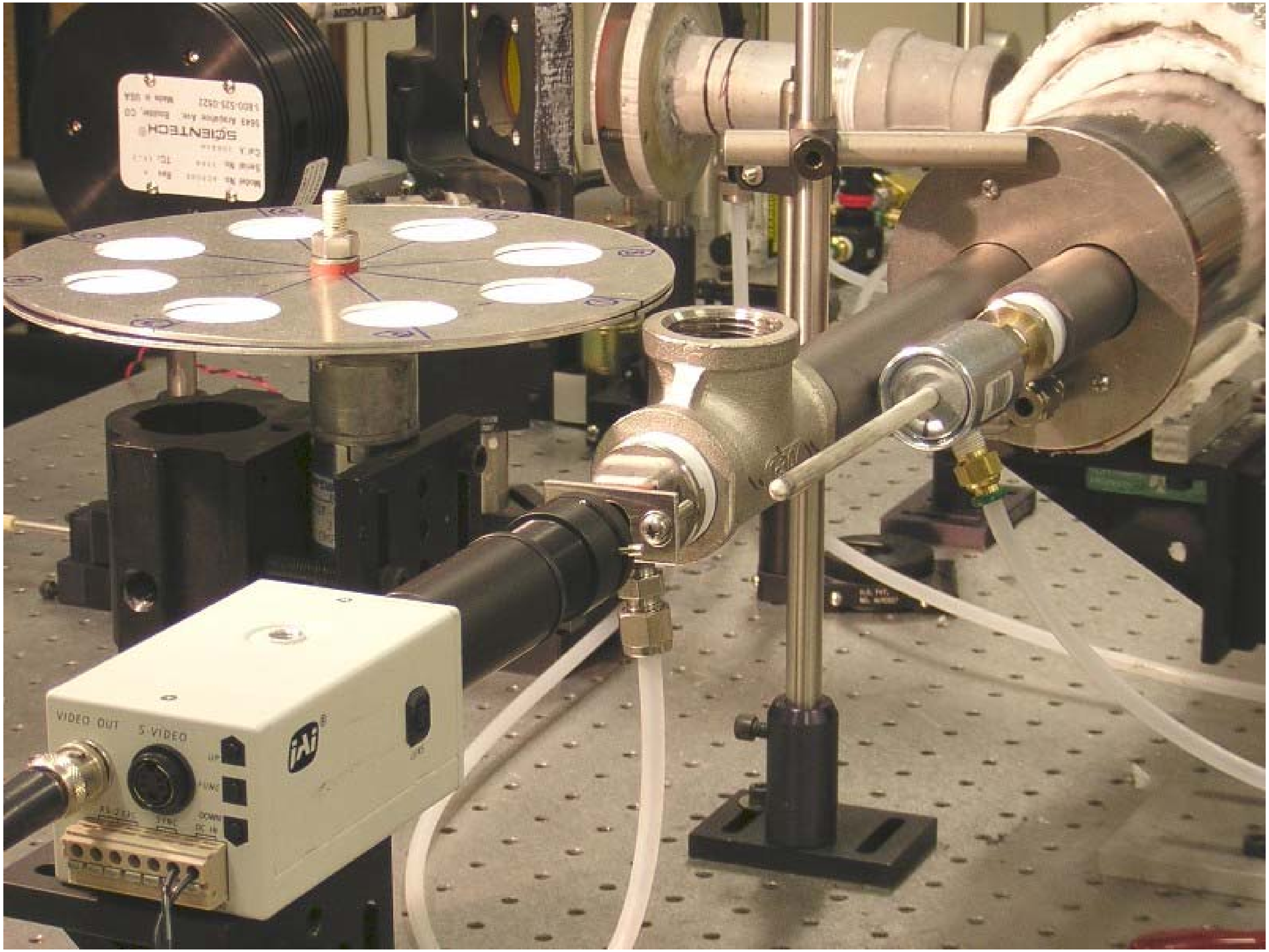
Chamber, Upstream End



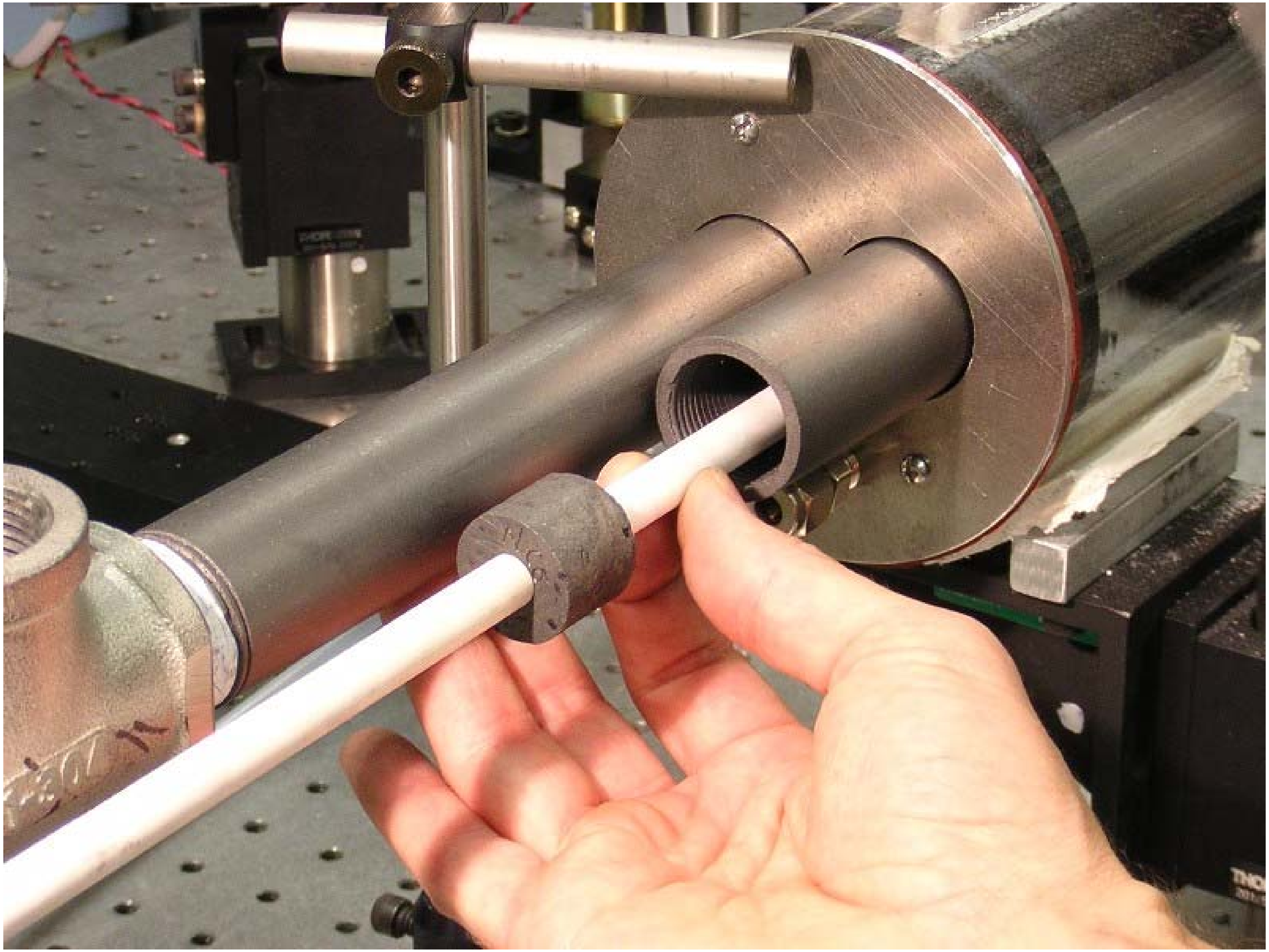
10.6 Micron Optics w/Motor Drives



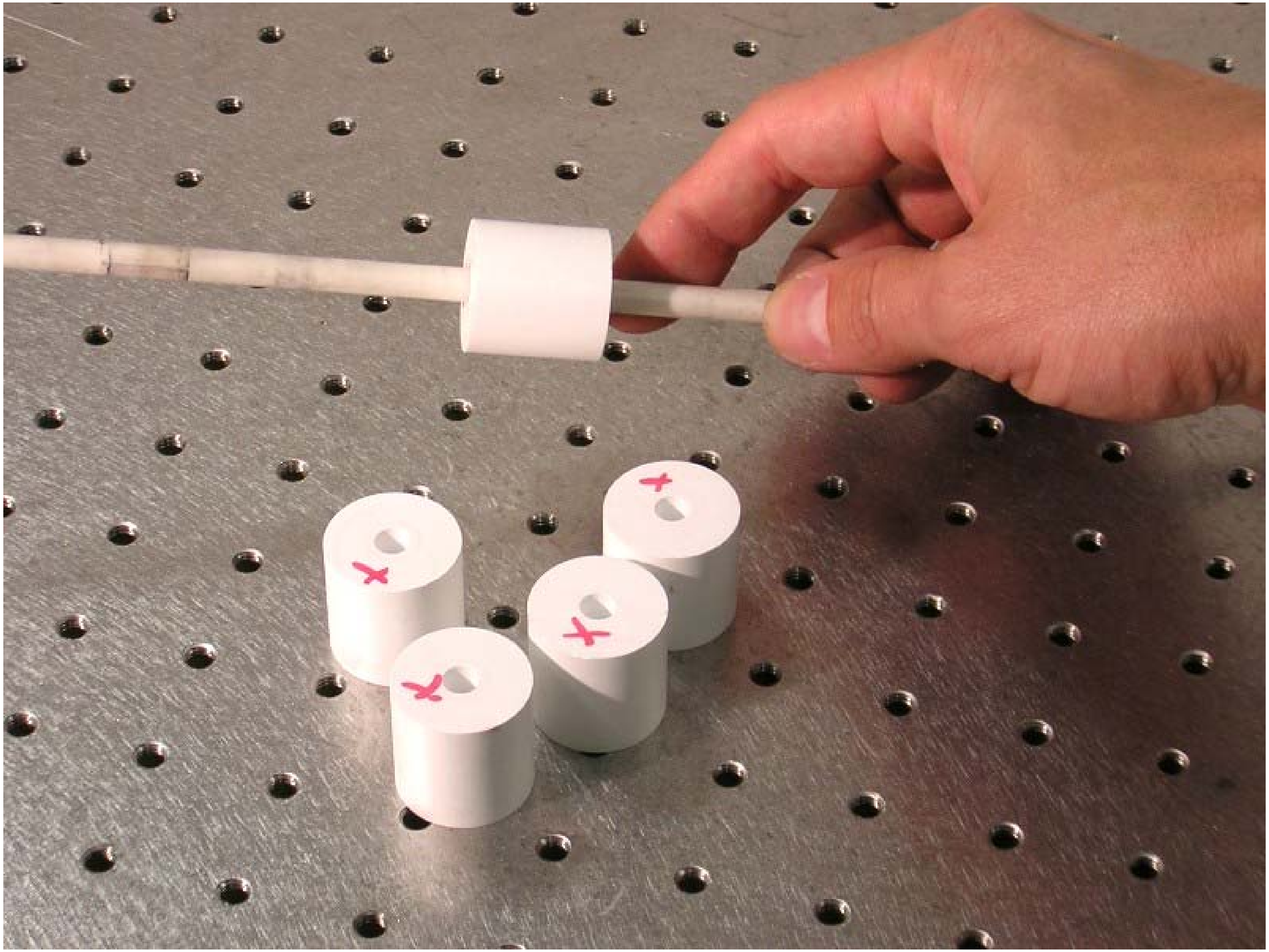
Filter Paper Collector Wheel



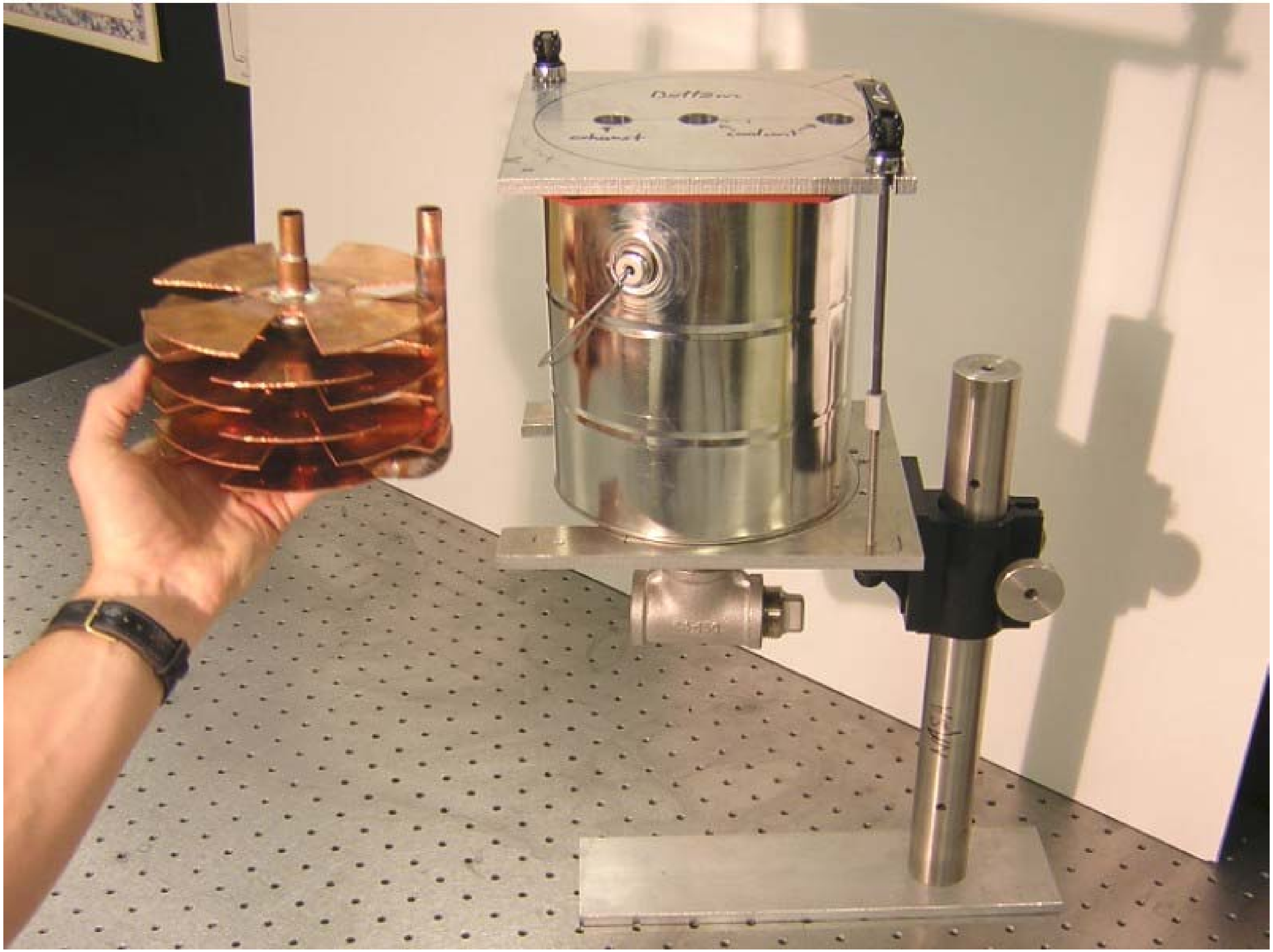
Target Loading



Boron Nitride Targets



Production Volume Collector



New Rig, Technical Improvements

- Variable geometry/heating profile construction.
- Pyrometer-controlled feedback heating to 1200 C and above (2000 C limit?).
- 10 minute warm-up, 15 minute cool-down (vs. hours for the old rig).
- Precision target positioning mounting and motion (20X the old spin rate with overlapping spiral capability).
- 2 minute target swap with precision holder.
- High throughput capability (heating and collection).

Synthesis Parameters to be Varied

- Wavelength (shorter is better?, plume interaction for controlled synthesis?).
- Watts/cm^2.
- Micropulse repetition rate (plume/plume interaction?)
- Dwell (ultrafast regime?).
- Catalyst (how low can we go in concentration?).
- Temperature and temperature profile.
- Flow geometry (plume/buffer gas interaction).

Why do Carbon Nanotube Synthesis Using The Jefferson Lab Free Electron Laser?

Answer: We have the opportunity to scale up to produce high quality nanotubes in 10 to 100 gram quantities for the fabrication of demonstration objects (things you can hold in your hand and test).

And, we have a completely unique synthesis path with unexplored opportunities for controlled synthesis.

The “killer app” is out there. Let’s find it here, first.

…quoted regarding the bulk manufacture of high quality nanotubes…

“No one is going to wait for an FEL to be built”

--Richard Smalley (1996 Nobel, Chemistry, Co-discover of C-60)