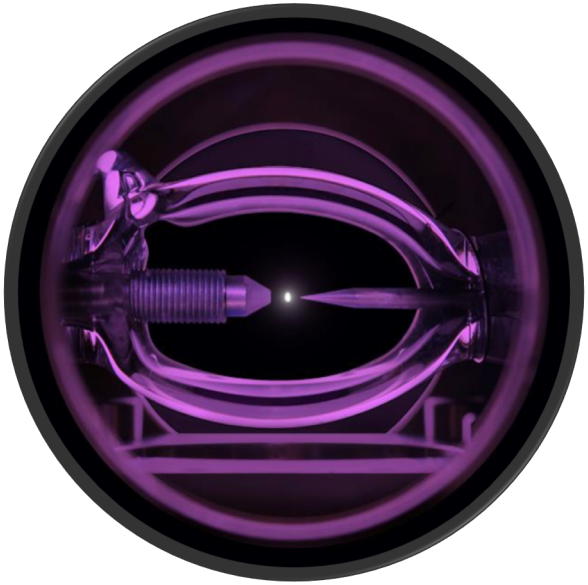
DEVELOPMENT OF APPLIED PHYSICS PRODUCTS IN START UP COMPANIES



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Perspective I'm Bringing

- My Role:
  - Scientist/Engineer/Inventor
  - Product Developer – Mostly semiconductor equipment hardware.
  - Manager as needed to bring products to success.
- Products
  - "Applied Physics Products"

    Highly technical, hardware, plasmas, E&M, power electronics, reactive gases.
- Markets:
  - Niche markets selling to scientists and engineers.
  - Part of a supply chain, OEM customers, big customers are other mfg. companies.
- IP
  - About 50 US patents, 2 jury trials, 1 settlement pre- ITC hearing.

Outline

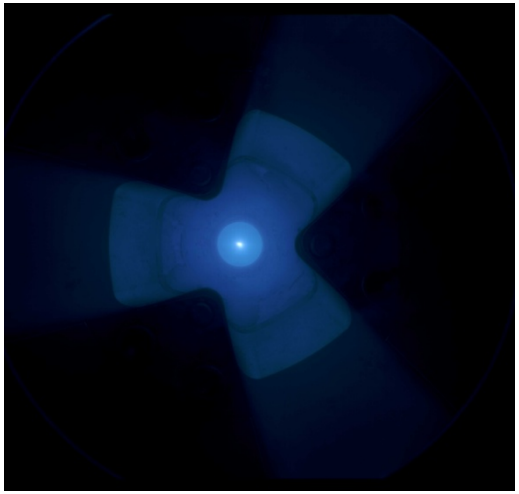
- A Time Line
- Products
  - Two products from Energetiq
- IP
- The Team
  - Long-term association /Self-selection, Continuity, Motivation
- Finance

Time Line

- 1981 MIT Plasma Fusion Center
- 1987 Microwave Plasma Technology (My Basement)
- 1988 ASTEX Founded
- 1994 ASTEX IPO
- 1998 Compact Instruments Founded
- 2000 MKS Instruments Acquires Compact Instruments
- 2001 MKS Instruments Acquires ASTEX
- 2004 Energetiq Technology Founded
- 2017 Hamamatsu Acquires Energetiq

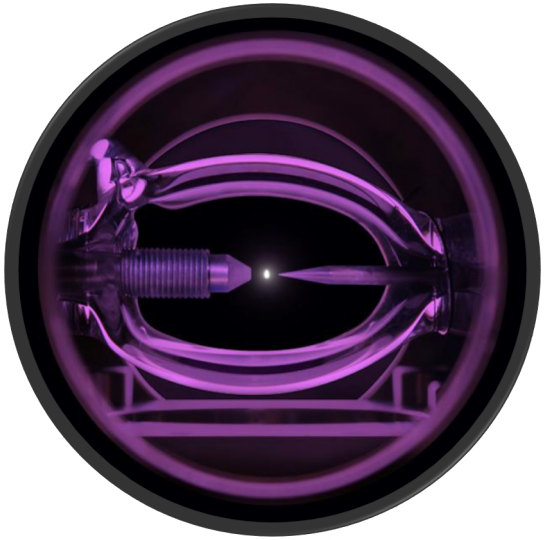
Two Technologies at Energetiq

A ➡ Start B ➡ Success



A) Electrodeless Z-Pinch™

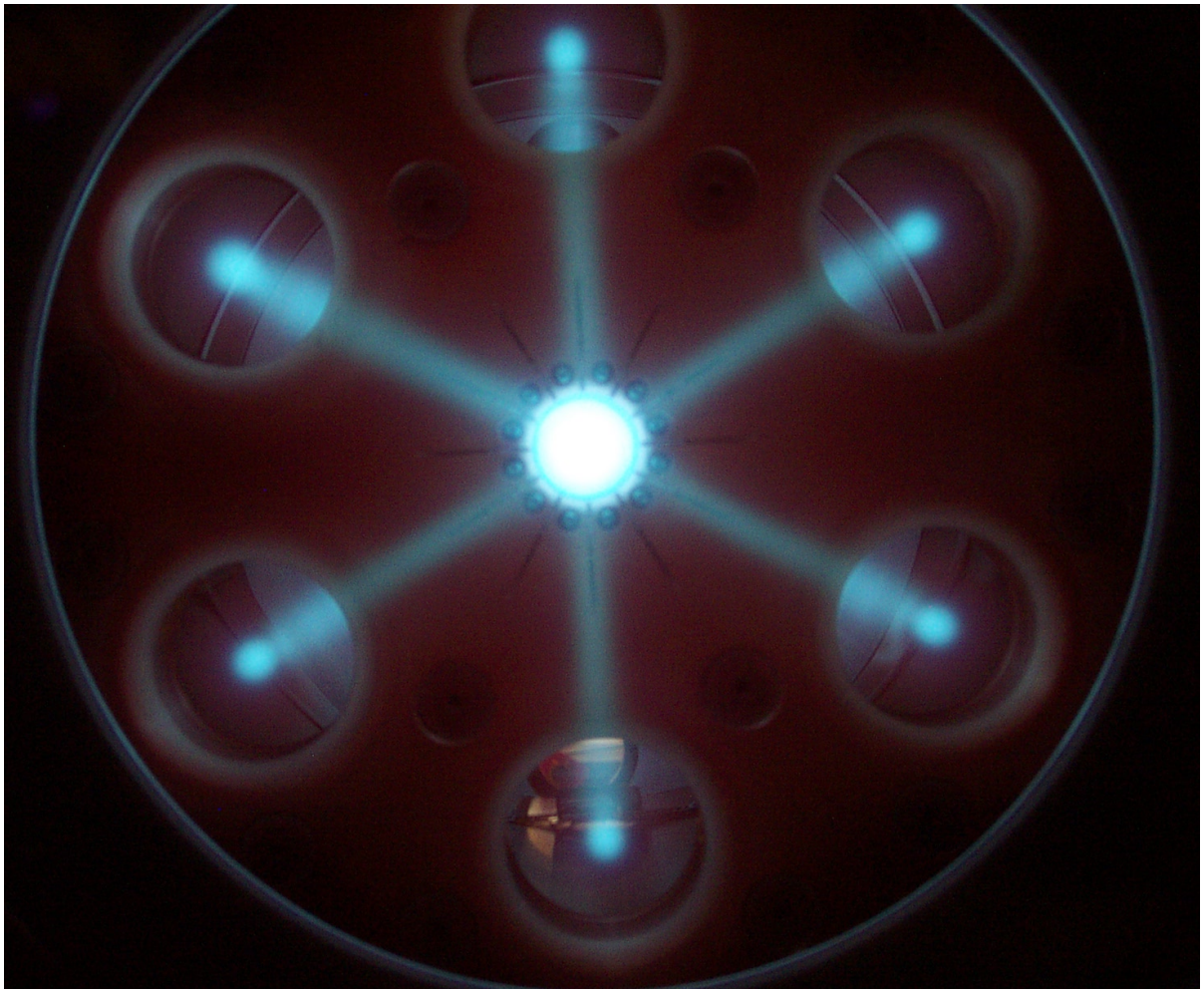
- High Power Electrodeless Pulsed-Plasma Technology
- High brightness 400 um diameter plasma
- 1 nm to 20nm output wavelengths



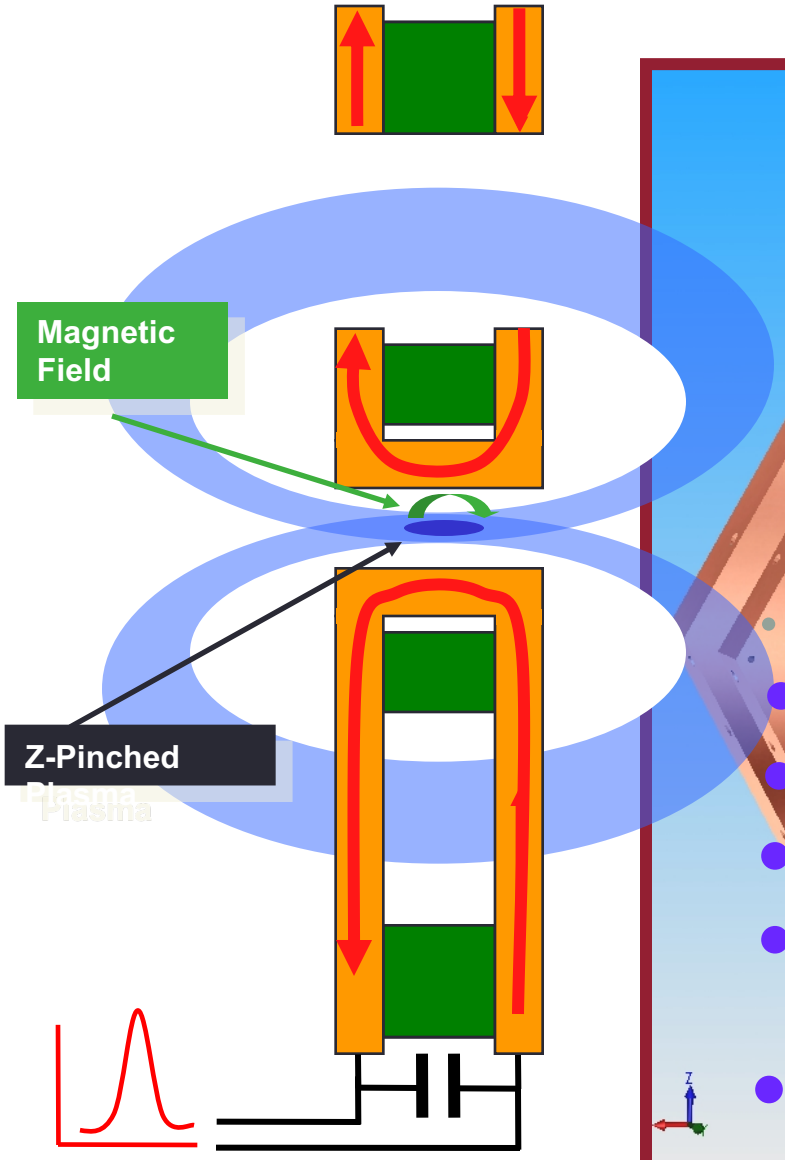
B) Laser-Driven Light Source (LDLS™)

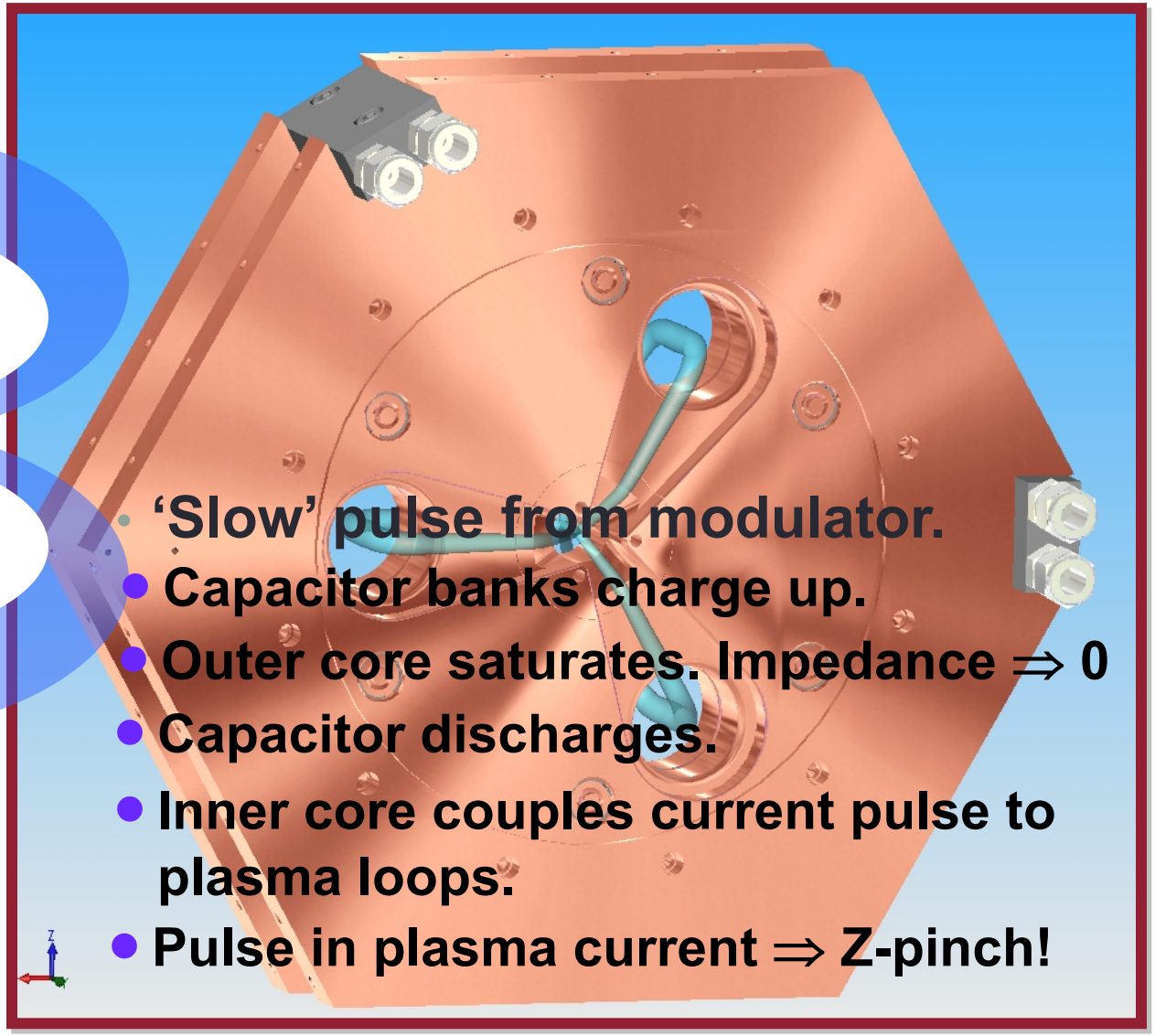
- Patented CW laser-produced plasma light source technology
- Very high brightness 100um to 200um size plasma
- 160 nm to 15 um continuous output spectrum

Electrodeless Z-Pinch

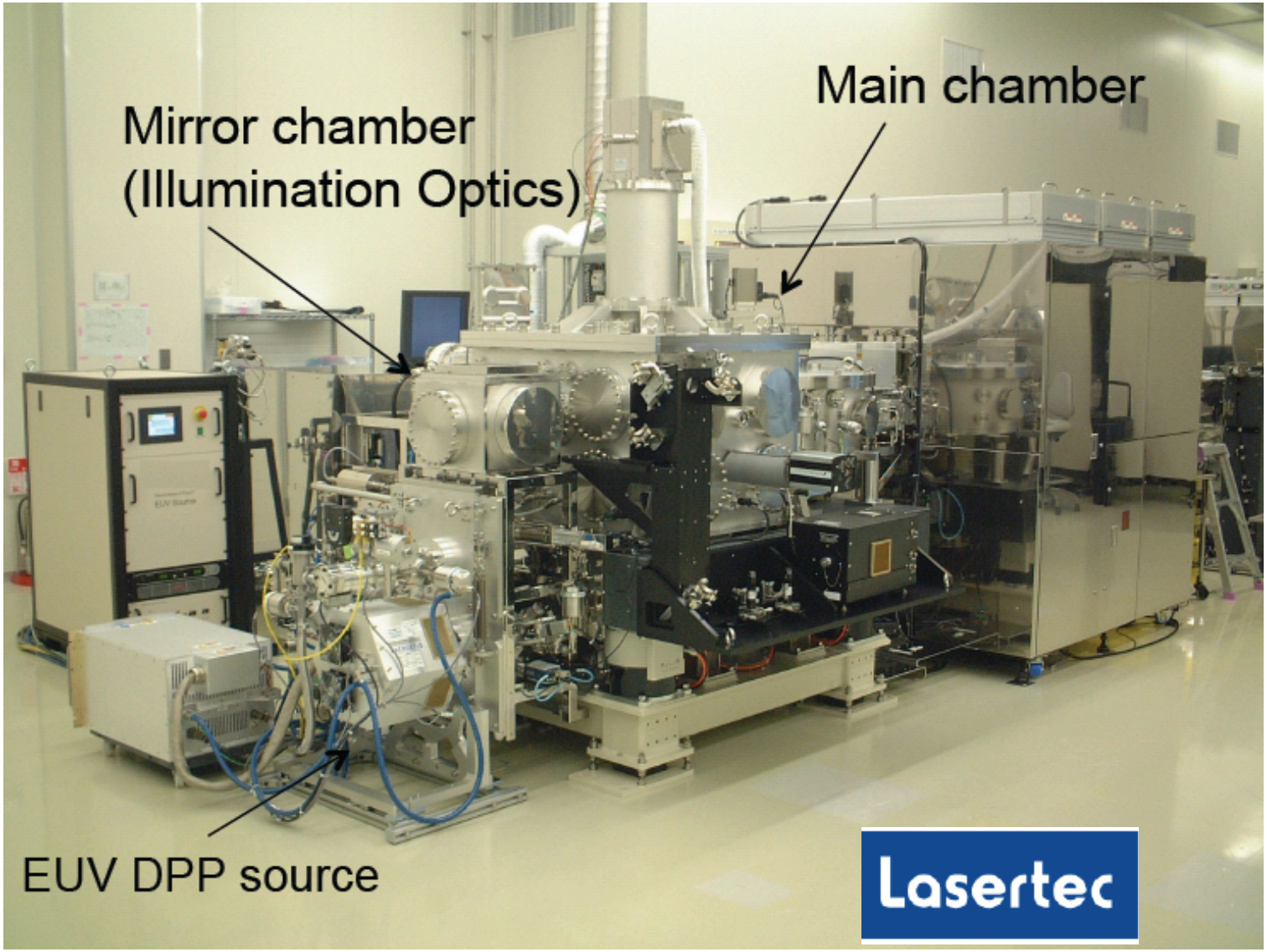


- Electrodeless Z-Pinch™
- Inductively driven current loops
- Single constricted high current region fed by parallel loops.



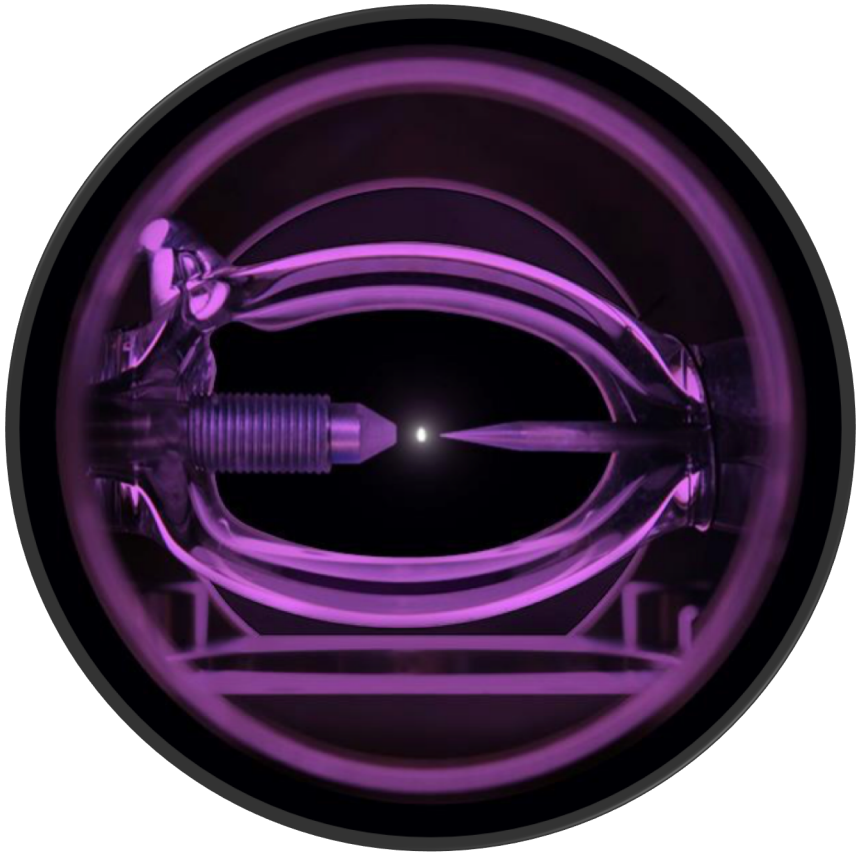


- ‘Slow’ pulse from modulator.
- Capacitor banks charge up.
- Outer core saturates. Impedance ⇒ 0
- Capacitor discharges.
- Inner core couples current pulse to plasma loops.
- Pulse in plasma current ⇒ Z-pinch!


Mirror chamber
(Illumination Optics)
Main chamber
EUV DPP source
Lasertec

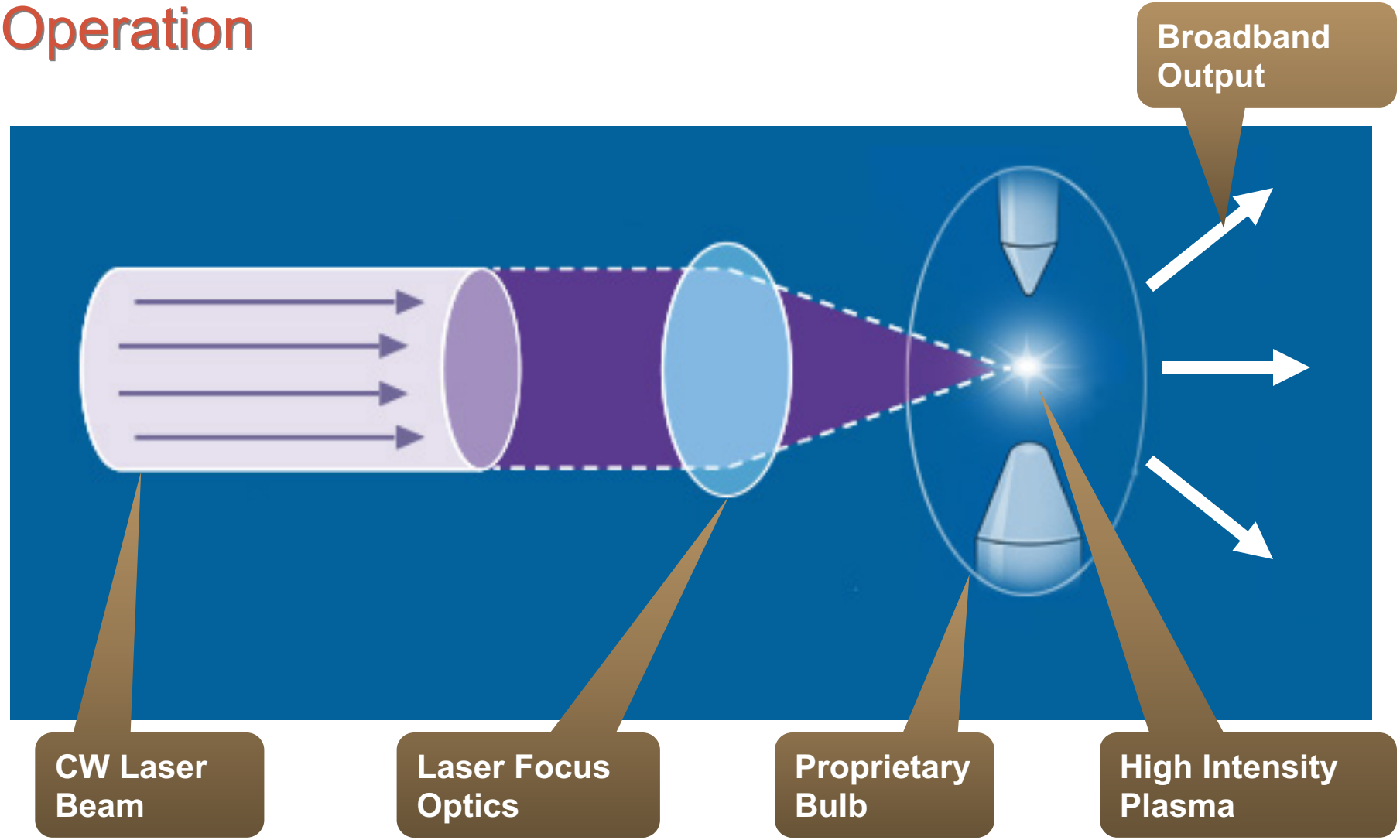
Laser-Driven Light Source **LDLS™**

A unique combination of valuable characteristics in a single light source:



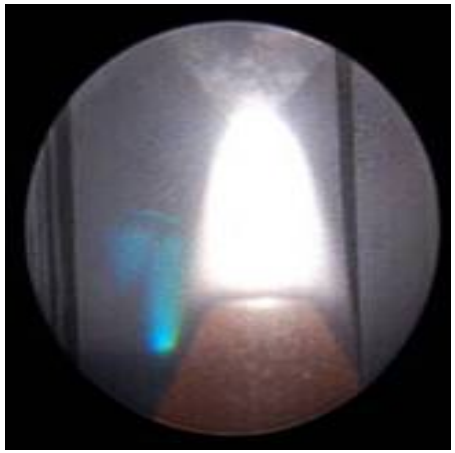
- Broad Spectrum: 170nm – 15um
- Highest Brightness/Radiance
- Longest Life with High Stability

Laser-Driven Light Source: Principle of Operation



Light from Arc-Lamp and LDLS

Xe Arc-Lamp



LDLS

- **High brightness: ~100 um diameter Xenon plasma,**
- **Efficient coupling into small fibers or spectrometer slits**

Source of a Product Idea

- A customer had a problem
  - KLA-Tencor ($4B Rev.) makes tools to inspect patterned wafers
  - Existing light source placed hard limit on throughput
  - Value of tool is proportional to throughput
  - Need 10X brighter light source
- They saw our EUV light source
  - Can we do that in DUV, CW , Broad-band?
  - No, but it's a challenging problem and we will work on it.
  - Also, the value of a solution is high.

The Invention

- Existing light source was xenon/mercury arc lamp
  - Fully mature technology, no hope for 10X.
  - The ideal “arc lamp” is a small ~100um black body with 10X more power per unit emitting area.

- How do you put 10X more power into a suitable target?
  - Laser
  - Will that work? Laser focused into high pressure xenon?
  - No. Absorption at practical laser wavelengths is too weak.
    - NRL Plasma Formulary – inverse bremsstrahlung.
  - But, it’s only too weak by about an order of magnitude and this is plasma physics after all.
  - Try it. Borrow a fiber laser, buy some arc lamp bulbs on ebay.

* This is over simplified. A lot of literature research was done, but still went from idea to bench test in the month of December 2005.

The IP

- The LDLS product exists in a complex IP environment.
- We filed our first patent in March 2006 using the time after the initial bench test to gather more complete data and do more literature research.
- Importantly, we filed various continuations and CIP over the following years, about 9 US patents, many foreign.
- We licensed some IP to our customer.
- We enforced the IP against another customer who built an infringing product.
- Ultimately the strong IP and the enforcement was key to a high valuation of the company.

Patents in General

- Find a patent lawyer who understands your technology.
  - This is worth a lot.
- Get the patent right. Make sure you understand and agree with everything in it. If it can be made more clear and complete, do that.
- Stay engaged. Don't throw it over the wall.
- Enforcing patents is expensive. See Finance section.

IP in General

- Many customers will see value in doing deals with you which encumber your IP. These deals may be good for you, too.
- Make sure contracts are as limited as possible. Don't give up anything you don't have to. Understand everything in IP agreements.
- Stay engaged. Don't throw it over the wall.

The Team (in the beginning)

The Team

- The photo is of the TARA group at MIT (Mike is in the middle)
- I quickly count 14 people (including three ASTeX founders) in the photo plus 4 others who worked for many years at ASTeX, Nexx and Energetiq.
- These companies involved hundreds of people over many years, but especially in product development the value of starting with a team you know and continuing to build a self-selected long term collaboration is large.

The Team – Sharing Success

- In these start-up companies we provided for good salaries, health care benefits and equity participation from the beginning. And a nice facility to work in. See Finance section.
- I don’t think a lot of austerity is a good idea.
- Six founders at Energetiq started with various amounts of common stock plus preferred stock if they were able to invest cash.
- All employees received options as part of their compensation and as a hiring incentive.

Financing of Energetiq

- Energetiq was started with about $750K in cash.
- About one year later after a prototype was running and we had engaged with Intel we raised about $3M from individuals whom we new or had connections with.
- Subsequently we raised two more rounds involving Intel Capital, Shea Ventures and Ushio. Total financing raised was about $16M.
- IP generated several million in license royalties which provided non-dilutive cash for LDLS development.

Financing in general

- Get a lawyer who has lots of experience with start-up, high tech, growth companies.
- Structure the company properly for investors and a future exit.
- Friends, angels and previous investors are a good way to get started. If you have a track record this is easy, if not a little harder.
- Good business plan. Convey your excitement, commitment and talent to potential investors.
- Traditional venture capital is difficult for hardware companies unless you are in a niche which is trendy.
- Strategic investors can be a better match, Intel Capital or Ushio in our case.

Thank You