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 \( \Rightarrow 0 \)
- Capacitor discharges.
- Inner core couples current pulse to plasma loops.
- Pulse in plasma current \( \Rightarrow Z\)-pinch!
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

- CW Laser Beam
- Laser Focus Optics
- Proprietary Bulb
- High Intensity Plasma

Broadband Output
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 knew 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