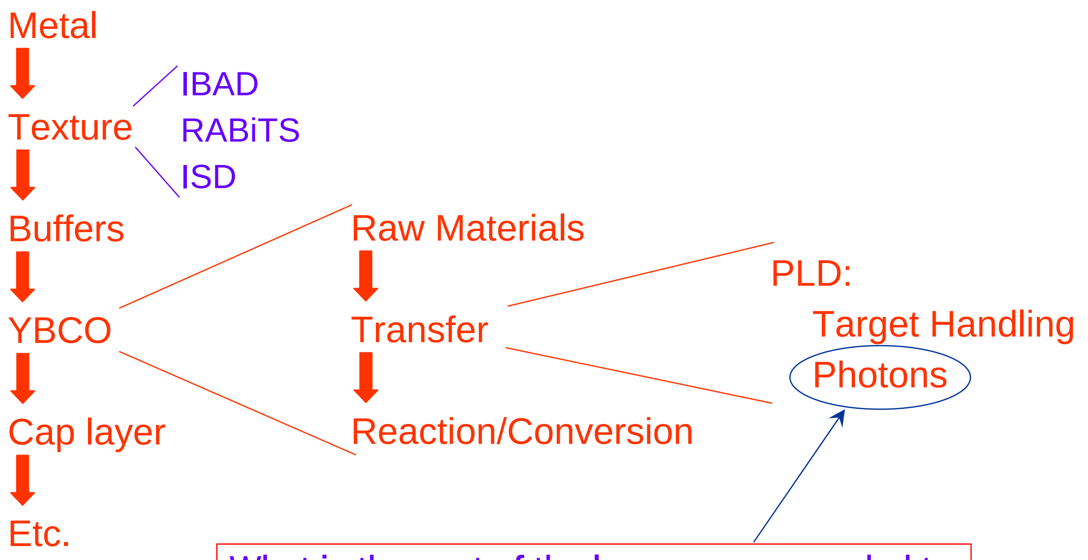
Scope of cost model (*"is PLD too expensive?"*)



What is the cost of the laser energy needed to produce 1 kA-m of coated conductor?

Elements of the cost model

1. Energy needed to grow the superconductor (MJ/kA-m)
   1. Cost to grow a unit volume of YBCO (ablation rate, collection efficiency)
   2. Volume of YBCO required for 1 kA-m (J_c)

2. Cost to produce a MJ of optical energy ($/MJ)
   1. At current laser costs
   2. Reduced prices due to market size (speculative)

➔Laser cost per kA-m of tape

Energy needed to grow the superconductor

Literature values:

- Energy power (W)
- tape speed (m/hr), tape width (cm), YBCO thickness (µm)

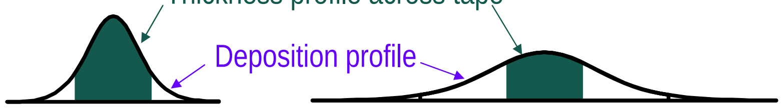
• Data presented at 2003 Wire Workshop (LANL):

48 kJ / (m·cm·µm)

Possible improvements: Gain up to a factor of 4 by

• Optimizing laser beam path

• Optimizing collection efficiency (laser spot, accept non-uniform thickness)



• Energy needed: 48 kJ / (m·cm·µm) [demonstrated] to
12 kJ / (m·cm·µm) [optimistic]

Energy needed per kA-m (dependence on J_c)

• Demonstrated:

J_c > 1 MA/cm^2 on moving tape

using 48 kJ / (m·cm·µm):
energy needed: < **480 kJ / kA-m**

assuming 12 kJ / (m·cm·µm):
energy needed: **120 kJ / kA-m**

• Possible (when?):

J_c = 2.5 MA/cm^2 (yields 1000 A-cm width at a thickness of 4 µm)

→ cost savings of 60%!

Energy needed: 48 kJ / kA-m

Oak Ridge National Laboratory
U. S. Department of Energy
Hans Christen, January 2003
UT-Battelle

LAMBDA STEEL series: STEEL 1000

Wavelength:
308 nm

Max. stabilized pulse energy:
1000 mJ

Max. repetition rate:
300 Hz

Max. stabilized average power:
300 W

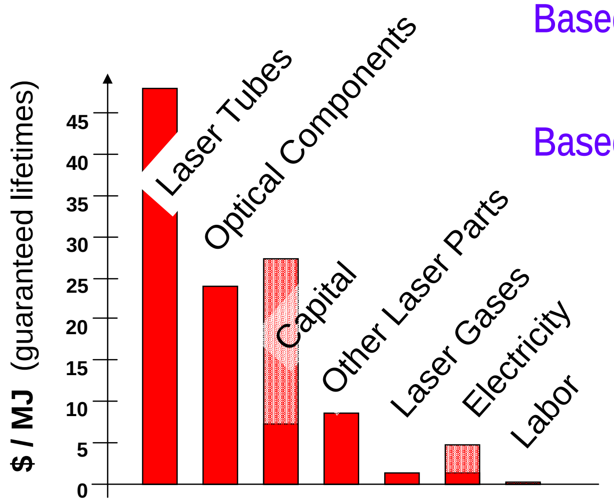
LAMBDA PHYSIK

Laser Costs

- Fixed costs
  - Floor space (5 m^2, *ignore*, possibly similar to other methods)
  - Static lifetimes (*ignore*, negligible when operating at high duty cycle)
  - Depreciation, cost of capital
    - optimistic: 3% interest, 20 years
    - pessimistic: 8% interest, 5 years
- Variable costs
  - Labor
  - Electricity
  - Laser components: Tubes, Optical components, Thyratrons, Laser gases

Laser Costs: using data from Lambda Physik

- Calculation can be based on *expected* or on *guaranteed* lifetime values
- Example: Lambda STEEL 1000 (308 nm, 300 Hz)
- Assumption: 80% duty cycle, 7.26 billion pulses per year at 1J/pulse



Based on guaranteed lifetime values:
$ 90 – 115 / MJ

Based on expected lifetime values:
$ 60 – 83 / MJ

Comparison between lasers (→ *they're all about the same*)

	Pulse energy (mJ)	Rep. Rate (Hz)	Power (W)	Wave-Length (nm)	Pulse Length (ns)	Cost lo/hi ($/MJ)
Lambda STEEL 1000	1000	300	300	308	29	60 115
Lambda STEEL 670	670	300	200	308	22	76 120
Lambda STEEL 600K	600	300	180	248	20	112 151
Lambda NovaLine 100	400	250	100	248	25	105 195
CSI Lumonics IPEX 848	400	200	80	248	20	similar

Benefit of scale

Assumptions:

- 20,000 km/year of coated conductor
- 1000 A — 2×10^7 kA-m per year
- Using 48 kJ/kA-m: — 9.6×10^{11} J per year
- Lambda STEEL 1000 at 1 J/pulse — 9.6×10^{11} pulses per year
  - expected tube lifetime — 3×10^9 pulses ➔ 320 tubes/yr
  - need 133 lasers
    (note: this is not a major fraction of all Lambda STEEL lasers)
- Reducing the cost of the laser tube by 50% results in a decrease of 25% in the cost/laser energy
  - note: Lambda does not think that this is very likely, because there are already a lot of lasers in use.

Cost per kA-m (laser cost only)

- Demonstrated: 48 kJ / (m·cm·µm) and 1 MA/cm^2 — 480 kJ/kA-m
- Laser cost based on guaranteed lifetimes: \$ 90 – 115 / MJ — \$ 100/MJ

At demonstrated values:	**\$ 48 / kA-m**
Use expected lifetimes (save 30%)	**\$ 34 / kA-m**
Increase collection efficiency and beam path (save 75%)	**\$ 8.5 / kA-m (?)**
Obtain J_c = 2.5 MA/cm^2 (save 60%)	**\$ 3.4 / kA-m (?)**
Tube at half of today's price (save 25%)	**\$ 2.5 / kA-m (?)**