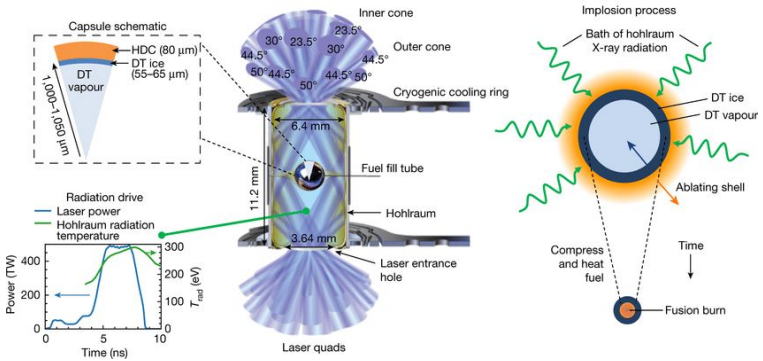
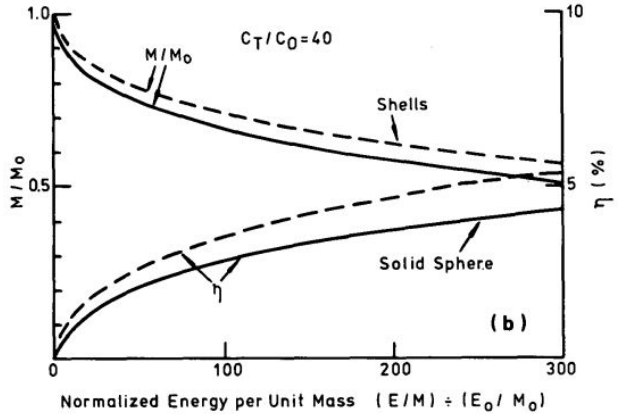
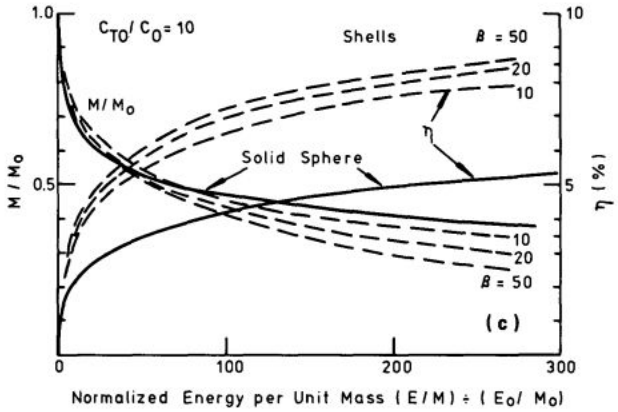
Laser Fusion

Inertial Confinement Fusion

- 1960: Ruby Laser
- 1970s: Laser Compression
  - 1976: Ablation Studies
- Laser-Plasma Interactions





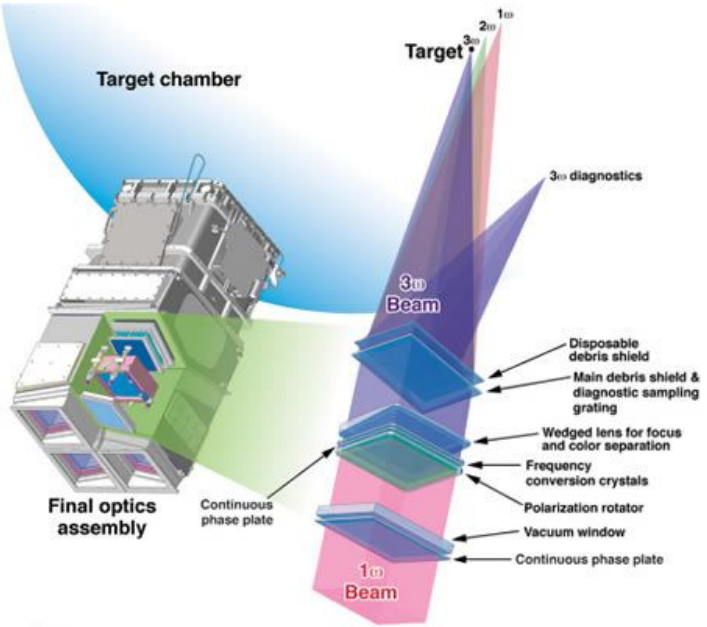


[1] https://iopscience.iop.org/article/10.1088/0029-5515/16/2/005/pdf
[2] https://www.nature.com/articles/s41586-021-04281-w
[3] https://ui.adsabs.harvard.edu/abs/1989LPB.....7..443P/abstract

Laser Specifications

- Prevent motion of pellet
  - Short time frame
  - Intense burst of energy
  - Isotropic distribution
- High frequency
  - Infrared generates suprathermal electrons, which excites the fusion pellets too early
  - NIF lasers are 1053 nm (IR), but uses KDP HHG to get to 351 nm (UV)

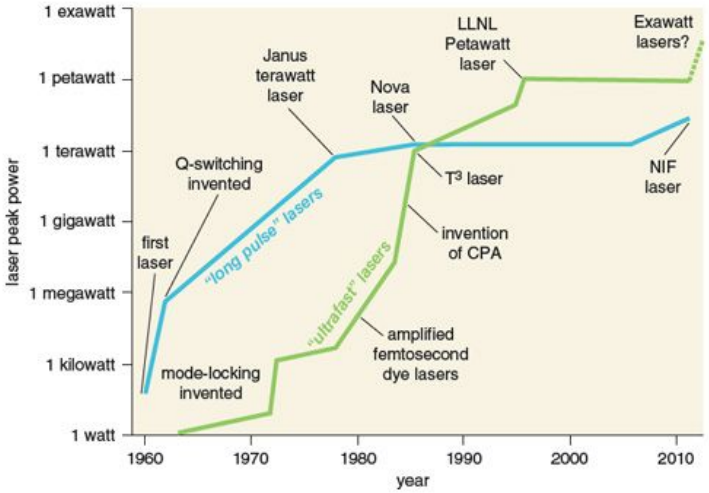
$$\varepsilon(\omega, k) = 1 + \chi_i + \chi_e = 1 - \frac{\omega_{pi}^2}{\omega^2} - \frac{\omega_{pe}^2}{(\omega - kv_0)^2}$$

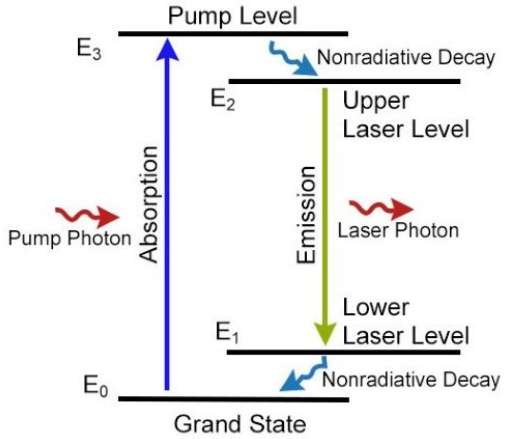


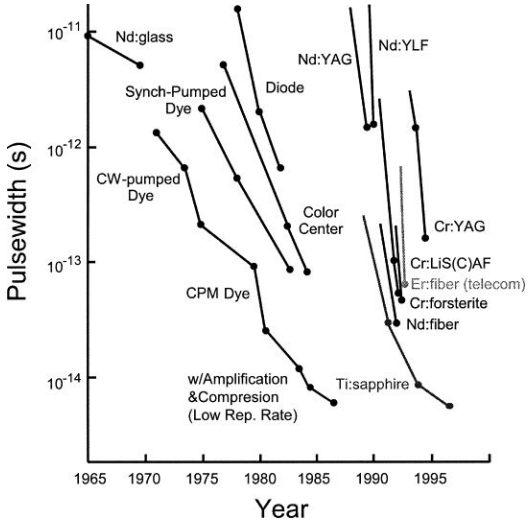
[4] https://www.nature.com/articles/s41467-019-12008-9
[5] https://lasers.llnl.gov/about/how-nif-works/final-optics

“Short” Time Frame

- Only require picosecond pulse widths



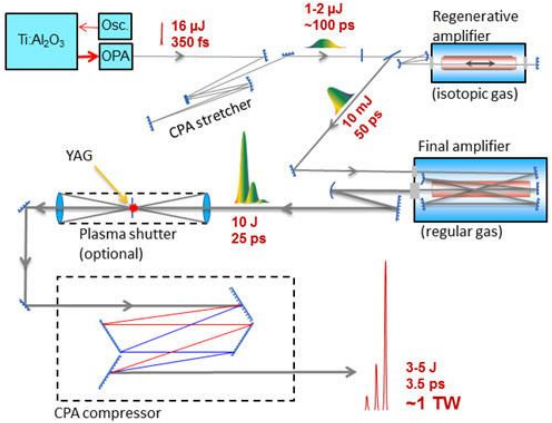


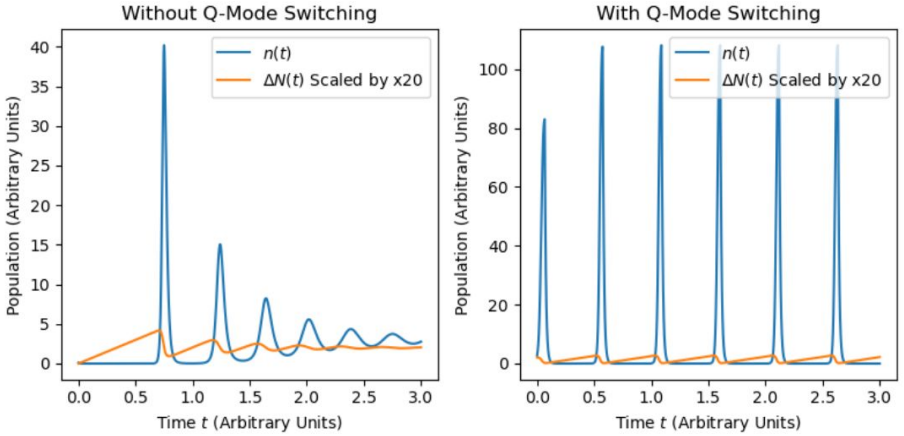


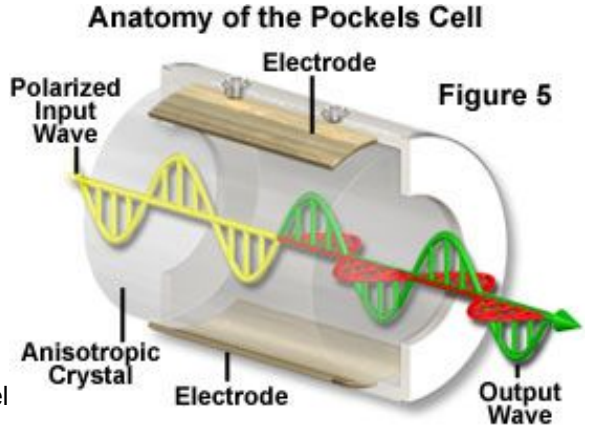
[6] https://www.gophotonics.com/community/what-are-nd-glass-lasers
[7] https://www.sciencedirect.com/science/article/pii/B0122274105003732
[8] https://www.americanscientist.org/article/high-power-lasers

Q Switching

- Generated by Pockels cell in NIF
- Can be used to stop laser signals through laser-plasma interactions



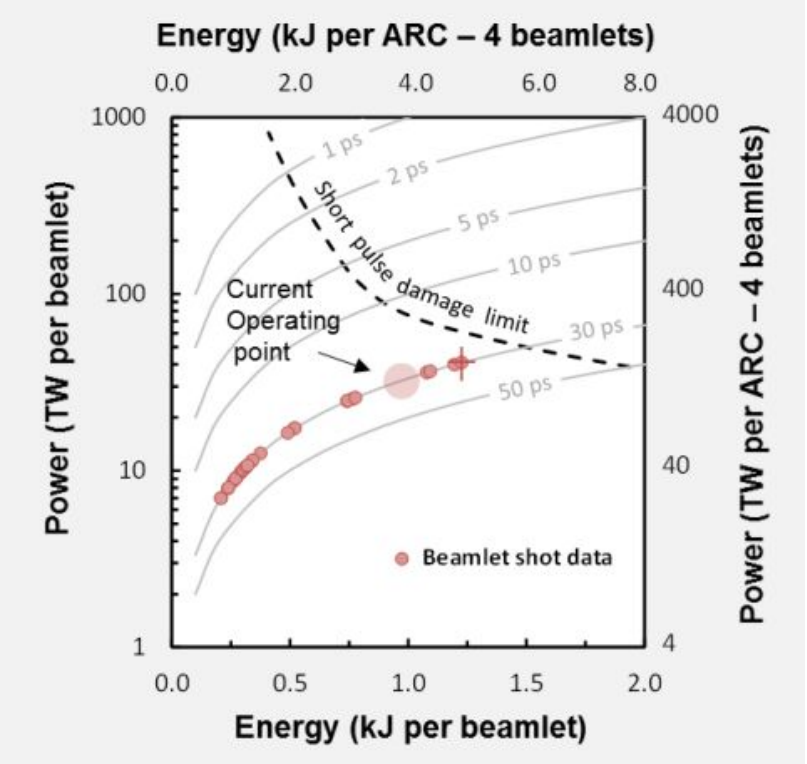




[9] https://www.olympus-lifescience.com/en/microscope-resource/primer/java/pockelscel
[10] https://www.bnl.gov/atf/capabilities/co2laser.php

High Energy

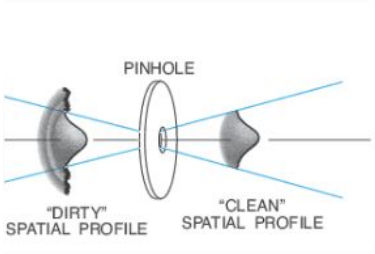
- Flash lamps directed at Nd-doped phosphate slabs provide high gain
- Chirped pulse
  - Picosecond initial pulse
  - Distribute intensity in time and frequency
    - Lower intensity permits lower damage limits to optical components
  - Pulse compressor (diffraction gratings) recombine pulse

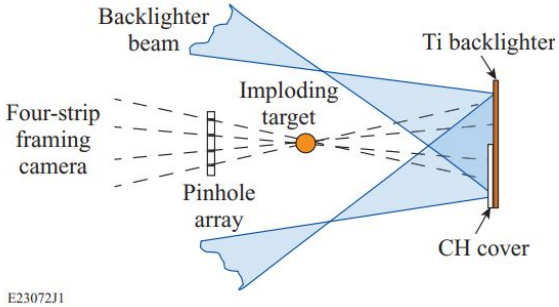


[11] https://www.osti.gov/servlets/purl/1343818

Other Components

- Double/tripler crystals
- Flash lamp amplifiers
- PEPC control gate
- Spatial filter
- Diagnostics





[12] https://lasers.llnl.gov/about/how-nif-works/amplifiers
[13] https://www.osti.gov/servlets/purl/15007302
[14] https://www.newport.com/n/spatial-filters
[15] https://lasers.llnl.gov/science/photon-science/arc
[16] https://pubmed.ncbi.nlm.nih.gov/25430361/
[17] https://pubs.aip.org/aip/pop/article/22/11/110501/109006/Direct-drive-inertial-confinement-fusion-A-review

Questions?