Basics of Laser Fusion

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INERTIAL THERMONUCLEAR FUSION

III Conference on Quantum Electronics; 1963

Paris,

N.G. Basov, O.N. Krokhin

$$D + D \rightarrow \begin{cases} He^3 + n \\ T + p \end{cases}$$

$$D + T \rightarrow He^4 + n + \varepsilon$$

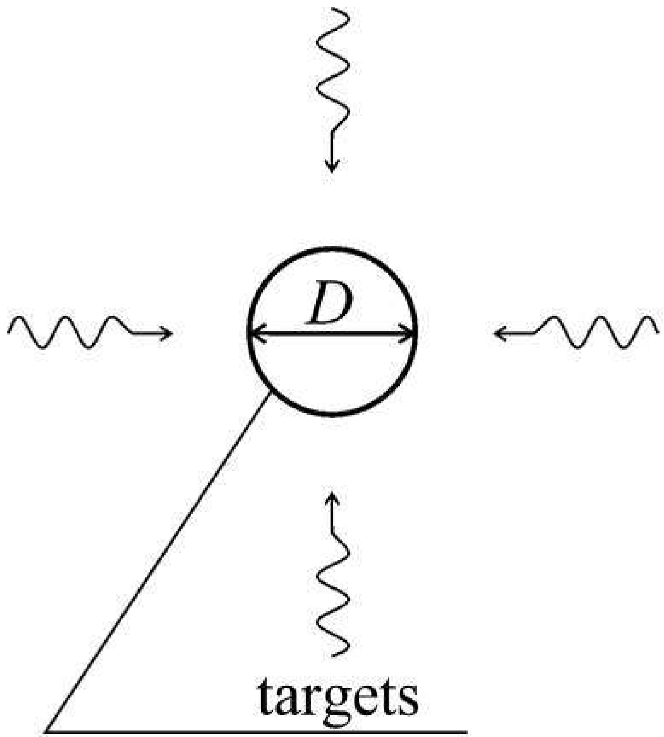
$$\varepsilon \approx \varepsilon_{fission}/10$$

1962

Emission: Modulated Q-factor of laser

100 J/1 ns (10^{-9} s)

$P \sim 10^{11}$ W $\sim P_{el}/100$



At focusing

$$J \sim \frac{P}{D^2} \sim 10^{13}\ \frac{\mathrm{W}}{\mathrm{cm}^2}$$

$D \sim 1\ mm$ (!)

Condition of positive energy yield

$$n \cdot \tau > 10^{14} \ s/\mathrm{cm}^3$$

$$T > 10^8 \ {}^\circ\mathrm{K}$$

τ − *plasma lifetime in a hot state*:

τ ~ *D*/expansion velocity

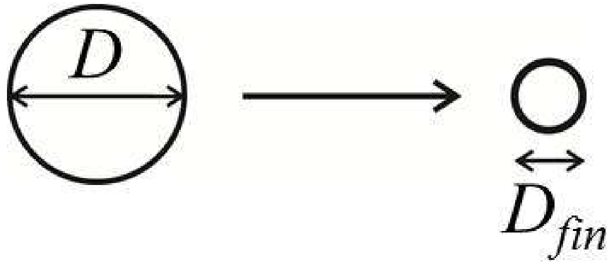
$$\begin{cases} D \sim 1 \ mm, \\ \text{velocity} 10^8 \ \text{см/с} \\ \tau \sim 10^{-9} s \\ n \sim 10^{23} \dfrac{1}{\mathrm{cm}^3} \end{cases}$$

The parameters converge (!)

Increase of the energy yield under compression

N.G.Basov, O.N.Krokhin. New Scientist 1970

E.Teller, J.Nuckolls et al. VII Conf. on Q.E., Montreal 1972



$$n_{fin} = n \cdot \left(\frac{D}{D_{fin}} \right)^3$$

$$\tau_{fin} = \tau \cdot \left(\frac{D_{fin}}{D} \right)$$

$$n_{fin} \cdot \tau_{fin} \sim n \cdot \tau \left(\frac{D}{D_{fin}} \right)^2$$

1968

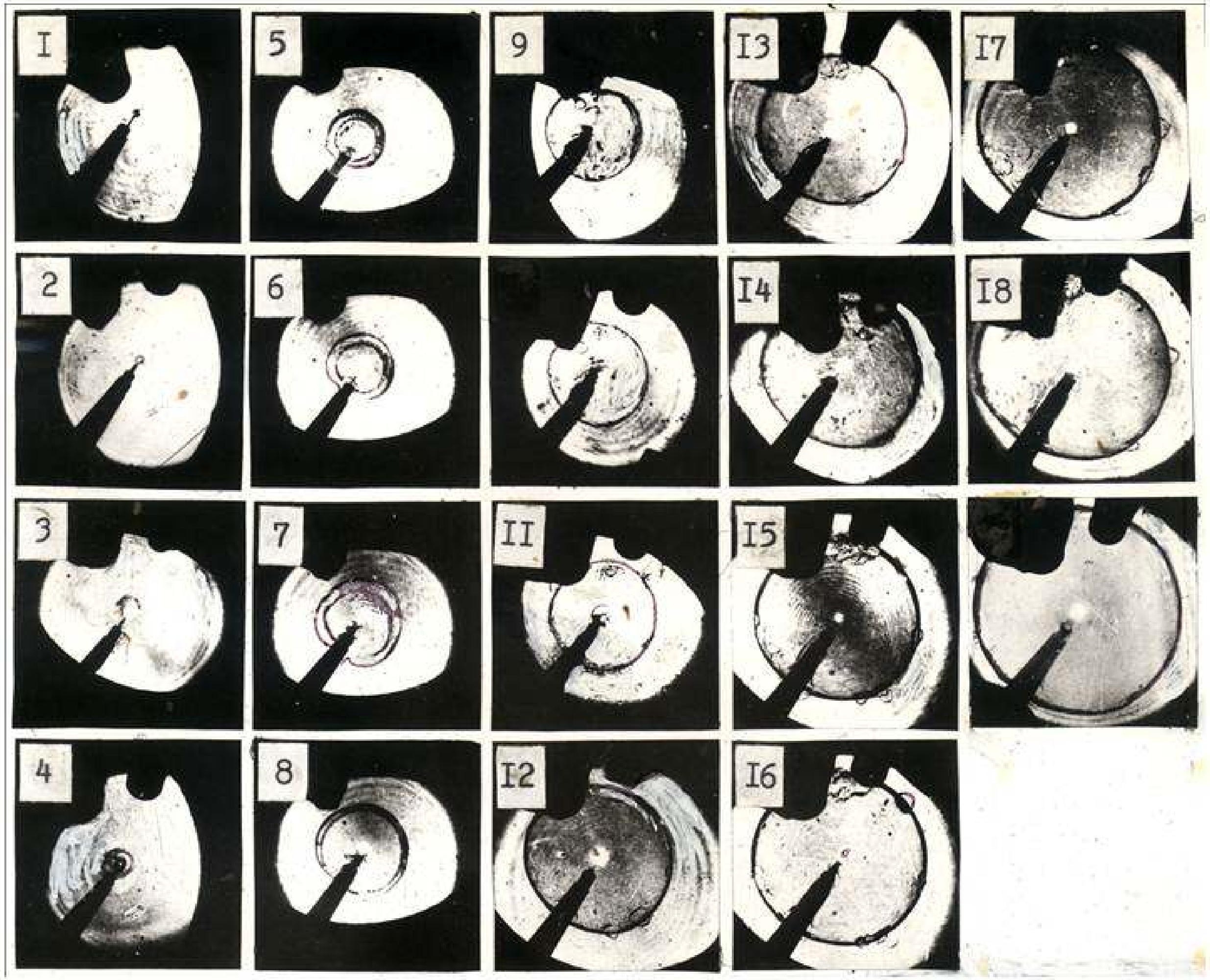
The discovery of a neutron yield, i.e. thermonuclear reactions D + D (FIAN)

1972

First experiments on spherical irradiation of a target with 9-channel laser installation «KALMAR» at FIAN.

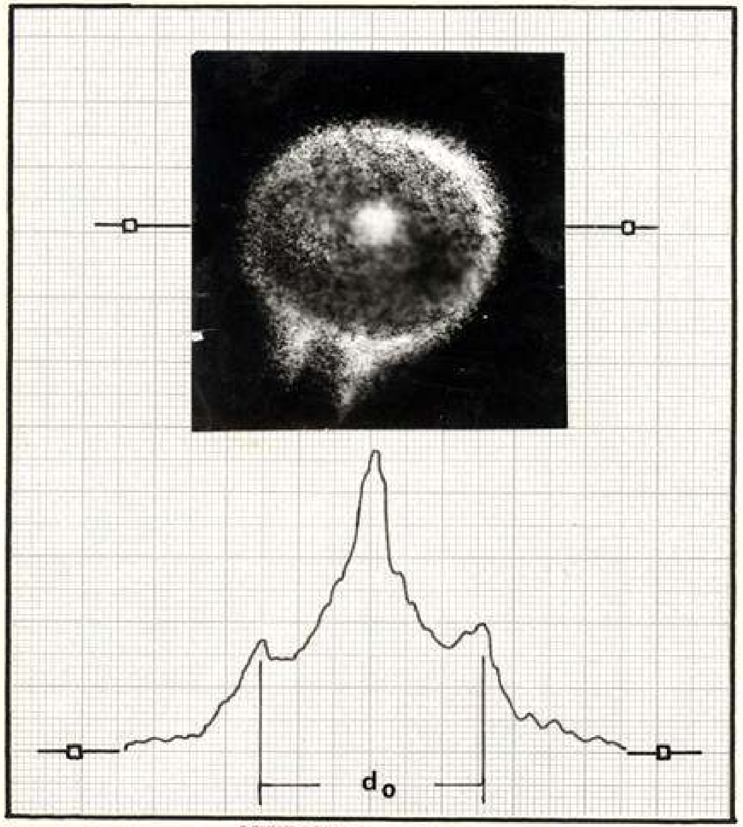
Neutron yield 10^5 (FIAN)

«KALMAR» 1972, The spherical shock wave created by laser target stimulated explosion.



ОПЫТ № 2073

E= 6II Дж.



мишень: стекло

d_o= 534 мкм ; ΔR =I,I мкм

A = 243.

Experiment № 2073
E=611 Дж

Target: Glass

«Dolphin», 1982

$$18 \times 3 \times 4 =$$

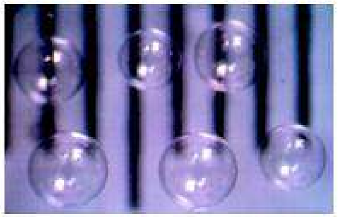
$$= 216$$

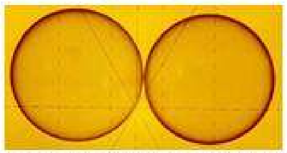
beams

Thermonuclear Target Laboratory was founded at FIAN in 1974. ***For more than 30 years the laboratory has been providing the scientific centers in Russia, England, Italy, Germany, France, Czechia, USA, India and China with the targets and production equipment.***

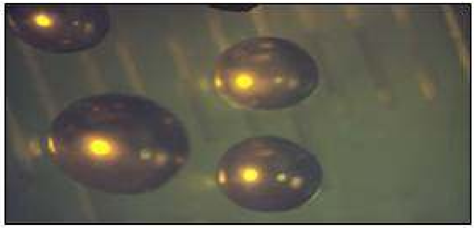
Gravity-type furnace for production of microspheres

Glass microspheres

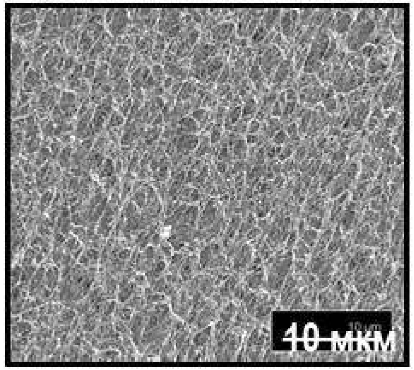




Polymer microspheres

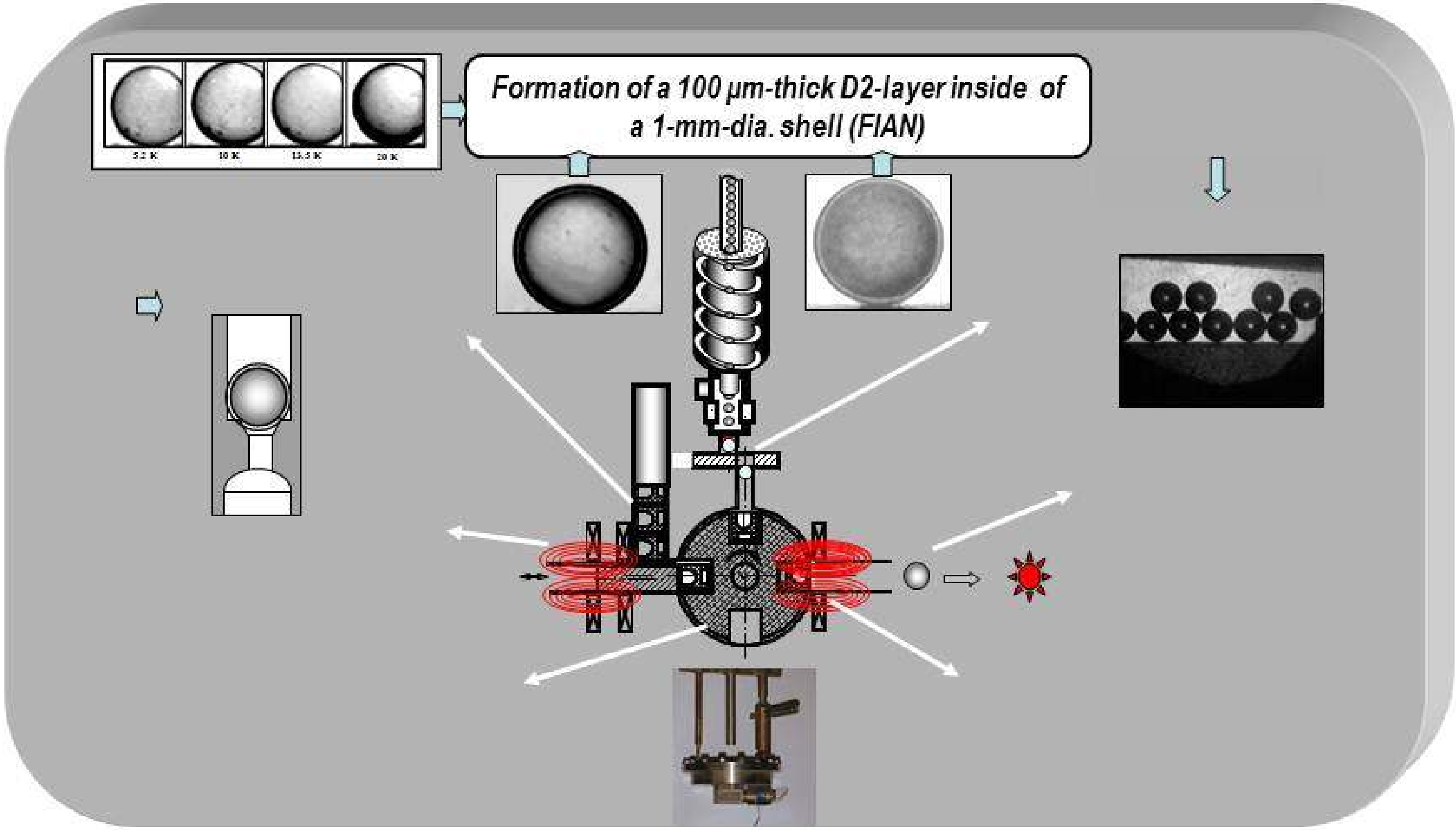


Au-coated polymer microspheres



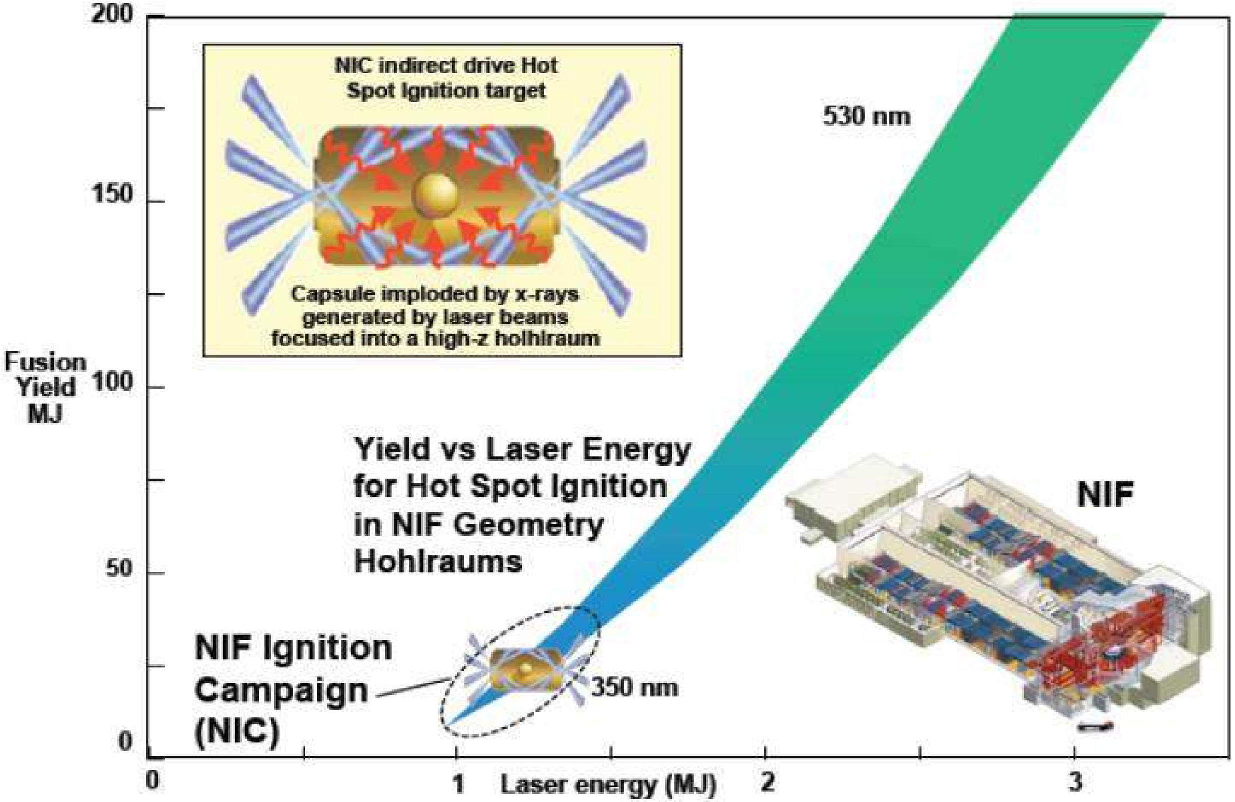
Polymer foam
Density: 0.001 g/cm^3

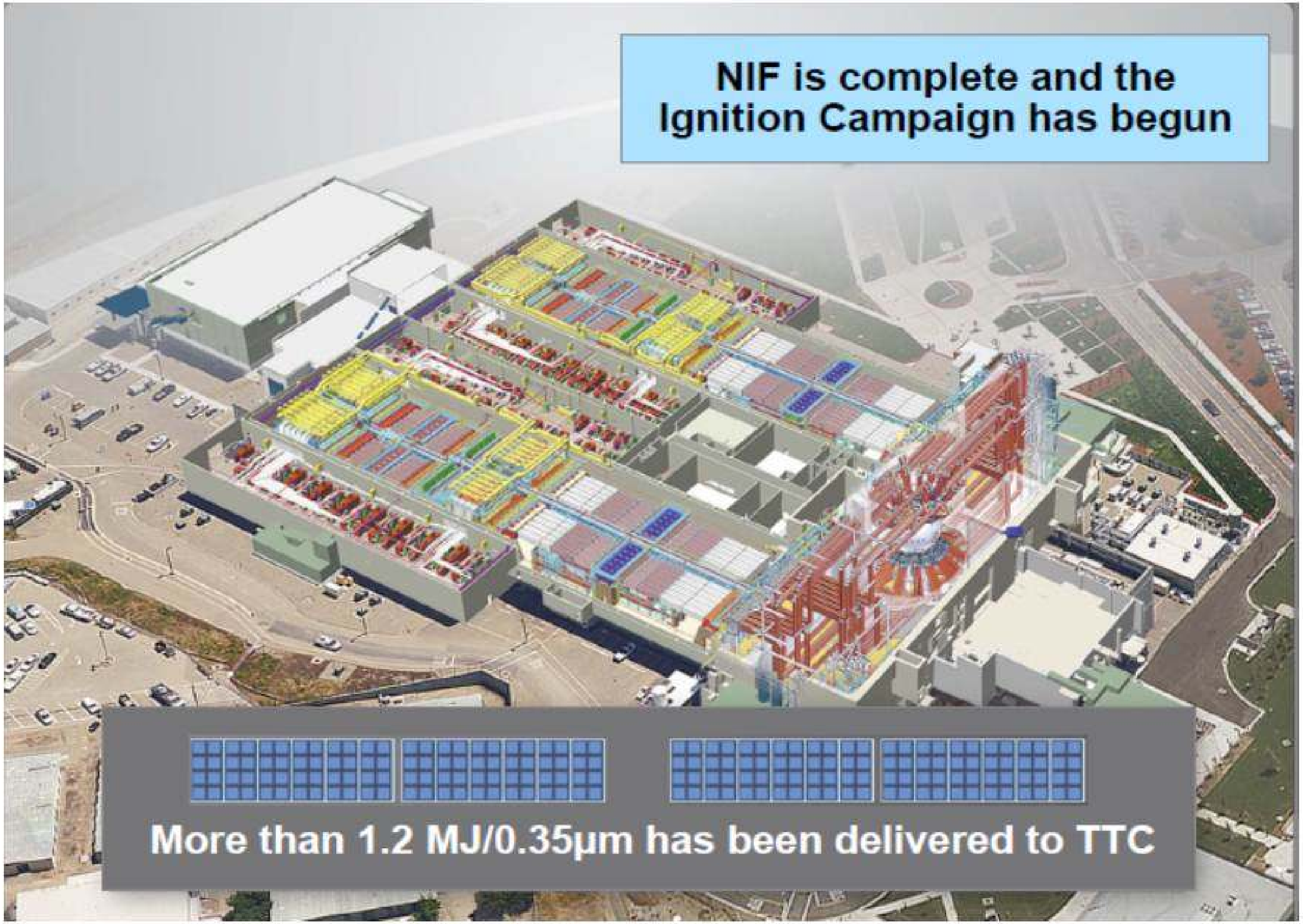
Production of cryogenic targets and injection with frequency 1-10Hz



Next step: system operational demonstration for the reactor-scale targets (including HiPER targets: Ø 2 mm)

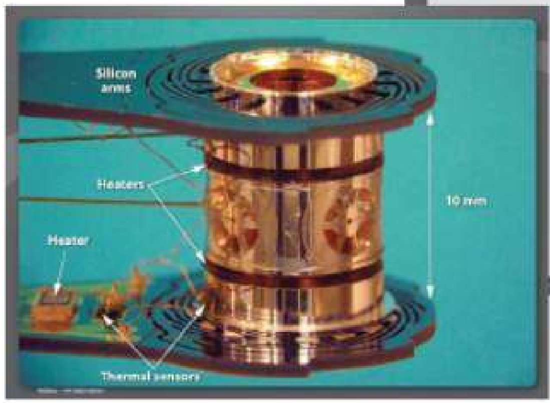
Ignition and gain on NIF will be a transforming event, and will focus the world's attention on the possibility of an inertial fusion energy option




NIF is complete and the Ignition Campaign has begun
More than 1.2 MJ/0.35μm has been delivered to TTC

Low fusion target cost is a key technical challenge

- NIF Targets are one-of-a-kind R&D devices
- Swiss watch manufacturing model; $10-100 K/unit
- LIFE targets require mass manufacturing model ¢/unit
- Raw material cost ~ 2¢/unit



Targets can be produced very cost effectively

- Targets will be made with technologies from high-volume manufacturing industries
  - Low-cost materials: pennies per component
    - Silicon mandrel: Ball bearing technology
    - High-density carbon capsules: CH4 pyrolysis
    - High-Z: <$.01 per target
    - Low-Z foam: SiO_2, Carbon
  - Automated fabrication/ assembly processes:
    - Laser drilling/machining of capsules
    - Stamped cones and hohlraums
    - Robotic assembly and packaging