

Objective

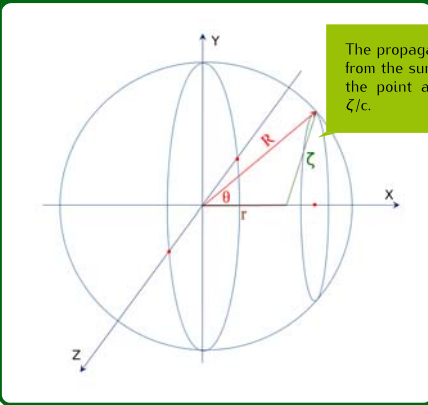
- Improving the development of *Inertial Confinement Fusion* (ICF), which is hindered by *Rayleigh–Taylor instabilities*.
- We offer a *configuration model* and analyze it for direct ignition *without an ablator*.

Considerations for the target

Alternatives in our investigations:

- same amount of *DT fuel*, *without compression* of radius $R = 640 \mu\text{m}$
- without ablator layer* as in [10, 11]
- target density is 1.062 g/cm^3
- absorptivity $\alpha_K \approx 8 \text{ cm}^{-1}$

Simple approximation



The propagation time from the surface point to the point at r equals $\tau = \zeta/c$.

The sphere of the fuel, with an internal point at radius r . Let us choose the x -axis so that it passes through the point at r and the center of the sphere. Then let us choose a point on the sphere, and the angle of this point from the x -axis is denoted by θ . Then the length between this surface point and the internal point at r is:

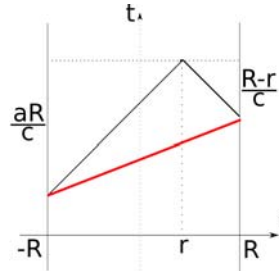
$$\zeta = (R^2 + r^2 - 2Rr \cos \theta)^{1/2} \quad (1)$$

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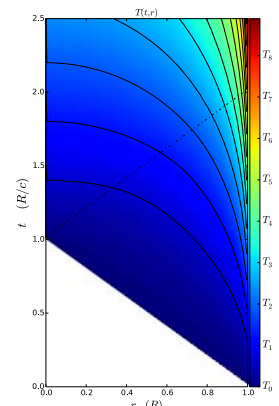
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Simplified model and its evaluation



↑ The boundaries of the integration domains, domain for the smallest τ -values cannot receive radiation, because the radiation started at $(R-r)/c$ earlier and it reaches the internal point at r later.



↑ The temperature distribution in function of distance and time.

We intend to calculate the **temperature distribution**, $T(r, t)$, within the **sphere**, as a function of **time**, t , and the **radial distance** from the center of the sphere, i.e. **radius** r .

We have **two steps** of the evaluation:

- we calculate how much **energy** can reach a given point at r from the outside surface of the sphere.
- we add up the **accumulated radiation** at position r , we integrate $dU(r, t)/dt$ from $t = 0$, for each **spatial position**.

Step 1:
The radiation at distance ζ is decreasing as $1/\zeta^2$. The total radiation reaching point r from the ribbon at θ is

$$dU(r, t) \propto \frac{1}{\zeta^2} \delta(\zeta - \sqrt{R^2 + r^2 - 2Rr \cos \theta}), \quad (2)$$

we integrate this for the surface of all ribbons.

Step 2:
Neglecting the compression and assuming **constant specific heat** c_v , **energy of the pulse** $Q = 2\text{MJ}$ $(4\pi)^{-1} (640\mu\text{m})^{-2} (10\text{ps})^{-1}$ and varying absorptivity:

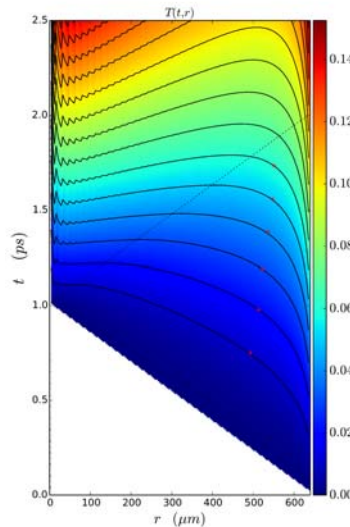
$$k_B T(r, t) = \frac{2\pi QR}{c c_V n} \begin{cases} 0, & \text{if } tc < R-r \\ \frac{\alpha_K(r)tc}{r} \left(\ln \frac{tc}{R-r} - 1 \right) + \frac{R-r}{r}, & \text{if } R-r < tc < R+r \\ \frac{\alpha_K(r)tc}{r} \ln \frac{R+r}{R-r} - 2, & \text{if } tc > R+r \end{cases} \quad (3)$$

The point (r_c, t_c) where the spacelike and timelike parts of the surface meet:

$$\left(\frac{\partial r}{\partial t} \right)_{T_c} = 1 \rightsquigarrow t_c = \left\{ \frac{2cR}{R^2 - r_c^2} \left[\ln \frac{R+r_c}{R-r_c} \right]^{-1} + \left(\frac{\alpha_K(r)}{\alpha_K(r)} \frac{c}{r_c} \right) \right\}^{-1} \quad (4)$$

Discussion

Numerical solution of the model for rapid ignition



Temperature distribution in function of r and t , dotted line is the light cone. The absorption coefficient is linearly changing with the radius. In the center, $r = 0$, $\alpha_K = 30 \text{ cm}^{-1}$ while at the outside edge $\alpha_K = 8 \text{ cm}^{-1}$. Temperature is in units of $T_1 = H \cdot R = 272 \text{ keV}$, and $T_n = n \cdot T_1$. The stars on the temperature contour lines indicate the transition from space-like front at the outside edge to time-like front in the middle.

- In this model estimate, we have neglected the **compression** of the **target solid fuel ball**, as well as the **reflectivity** of the **target** matter.
- The relatively **small absorptivity** made it possible that the **radiation could penetrate** the whole target.
- The **characteristic temperature** was $T_1 = 272 \text{ keV}$, below that the **ignition surface is time-like hyper-surface**, where **instabilities cannot occur**.
- The **detonation at a higher critical temperatures**, $T_c > T_3$ occurs after the radiation reaches from the other side.

Conclusion It is important to use the proper relativistic treatment to optimize the fastest, more complete ignition, with the least possibility of instabilities.