Channeling in Corona of Fast Ignition Targets

G. Li, R. Yan, and C. Ren, UR/LLE
T. Wang, J. Tonge, and W. B. Mori, UCLA
High-intensity ignition pulse can lose energy in underdense corona

- The ignition pulse power greatly exceeds self-focusing threshold
  - $P/P_c > 1$ for $n = 3 \times 10^{-5} n_c$ and $\sim 3000$ for $n = 0.1 n_c$
  - Indicating highly nonlinear interactions

- Ignition pulse can lose its energy and being reflected through underdense corona
Channeling makes ignition pulse more effective

- Two ways of avoiding loss in corona
  - Using attached-cone targets
  - Using a channeling pulse

- Key questions
  - Can a clean channel be created?
  - What are the channeling speeds?
  - How to distribute energy between channeling and ignition pulses?
Channeling in this regime has rarely been explored

- Previous PIC simulations on laser-underdense plasma interactions were for on lower intensities or shorter pulse lengths.
  - ICF compression phase: $I=10^{14-16}$ W/cm$^2$ (unable to create clean channels)
  - Plasma-based accelerators, $\tau\sim50$ fs (ion dynamics not important)
- We are doing PIC simulations with OMEGA/EP-like parameters
  - $\lambda=1$ $\mu$m, $I=10^{19}$ W/cm$^2$, $W_0=14 - 40$ $\mu$m
  - Plasma density rises from 0 to $1$ $n_c$ in $\sim$1000 $\mu$m exponentially
    - $\sim\exp( x/430$ $\mu$m)
    - $M_i/m_e=4590$ (DT), $T_i=T_e=0.35 - 1$ keV
- Two types of simulations in 2D
  - Two separate density region ($0.1 - 0.3$ $n_c$ & $0.3 - 1$ $n_c$, 10 particles/cell)
  - Single region ($0.1 - 1$ $n_c$, 1 particle/cell)
Clean channel can be established ($0.1-0.3 \, n_c$)

Ion density plot, CW laser, ~7 ps
Laser can propagate unperturbed in channel (0.1-0.3 $n_c$)

Laser e-field (s-pol)
Clean channel can be established (0.1-1 $n_c$)

electron density plot, CW laser, ~12 ps
Stages of channeling process

- Relativistic SF/Filament
Stages of channeling process

- Relativistic SF/Filament
- Ponderomotive SF/Filament
Stages of channeling process

- Relativistic SF/Filament
- Ponderomotive SF/Filament
- Filaments merging & shock launching
Channel advancing is stochastic

- Regular Transverse expansion
  - $V_t \approx 0.03c \sim 2C_s$ (at 500 keV)
  - Channel wider than laser width
- Longitudinal advancing involves many highly nonlinear processes
  - Plasma piling-up
Channel advancing is stochastic

- Regular Transverse expansion
  - $V_t \sim 0.03c \sim 2C_s$ (at 500 keV)
  - Channel wider than laser width

- Longitudinal advancing involves many highly nonlinear processes
  - Plasma piling-up
  - Laser hosing/channel bending
  - Channel bifurcation
  - Channel smoothing (self-correcting)
How long does it to take to get to $1n_c$?

- For $40\mu m$-wide beam it probably takes 20 ps (3.2 kJ)
- $v \approx (mn_c/Mn)^{1/2}a=0.04c$ (for $n=n_c$)
- The $14\mu m$-wide beam shows uneven advancing speed
  - Should take less than 80 ps
- 3D effects ($p$-pol vs $s$-pol)
How long does it to take to get to 1n_c?

• For 40μm-wide beam it probably takes 20 ps (3.2 kJ)
• \( v \approx (m_n c/M_n)^{1/2} a = 0.04c \) (for \( n = n_c \))
• The 14μm-wide beam shows uneven advancing speed
  - Should take less than 80 ps
• 3D effects (p-pol vs s-pol)
It will take blue light to channel to $10^{22}$ cm$^{-3}$

- Hole-boring from $1n_c$ to $10n_c$ takes $>300$ ps
- Tripling the frequency of channeling pulse can channel to $10^{22}$ cm$^{-3}$
Summary

- Clean channel can be created for $I=10^{19}$ W/cm$^2$
- Channel advancing is stochastic but self-correcting
- Channeling to $n=10^{22}$ cm$^{-3}$ requires 0.35-µm light