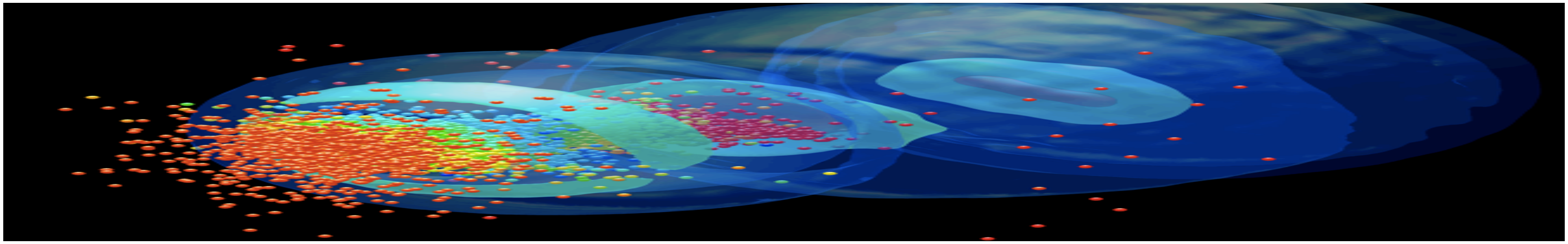


Key Physics Study of Laser Plasma Interaction (LPI) with Near Critical Density (NCD) Plasma Using Laser Machined Plasma Structure at ATF

Wei Lu

Tsinghua University

The 17th ATF User Meeting

Oct 15th 2014

Outline

- **Rich Physics of LPI with NCD plasma**
- **Issues with laser interacting with solid targets**
- **Advantages of using CO2 laser interacting with NCD gas target**
- **Plasma structure using laser machining method**
- **Proposed LPI experiment with current ATF capabilities**
  - **Study of laser radiation pressure acceleration (RPA) with very thin gaseous plasma target and the relevant transverse stability**

Rich Physics of LPI with NCD Plasma

- **The physics of relativistic laser plasma interaction with near critical density plasma is very rich, to name just a few:**

  laser self-focusing and channeling of plasma, laser filamentation,

  laser heating of hot electrons, fast electron transportation, magnetic field generation, radiation pressure acceleration and transverse instabilities, laser launched shockwave and shock acceleration ……

- **The detailed physics strongly depends on the plasma density profile, the scale length and the laser intensities, therefore a clear understanding of the physics requires great control of these conditions**

Issues with laser interacting with solid thin foils

- Target flatness and repeatability
- impurities on surface
- laser contrast and prepulses
- no easy optical diagnostic to see through the dense plasma

Advantages of using CO2 interacting with gas target

- Flatness and purity can be controlled
- Optical diagnostics to see what is going on
- Less demanding on laser contrast
- Prepulse effects can be diagnosed

Current limits of gas target

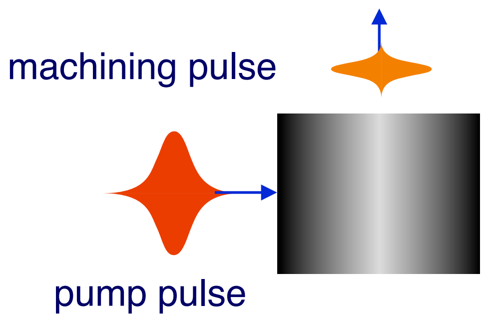
- Not easy to make very thin target (on the order of laser wavelength) for RPA study

- Hard to control or tune the density profile

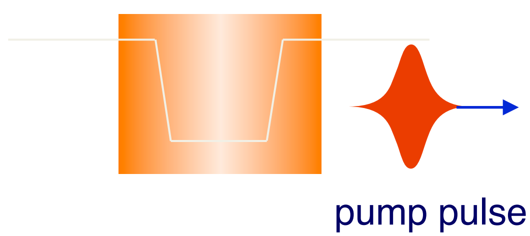
Laser machining of gas target has the potential to address these two issues elegantly

Reduction of local plasma density by laser machining

Step 1: A prepulse ionizes and heats up the gas target.



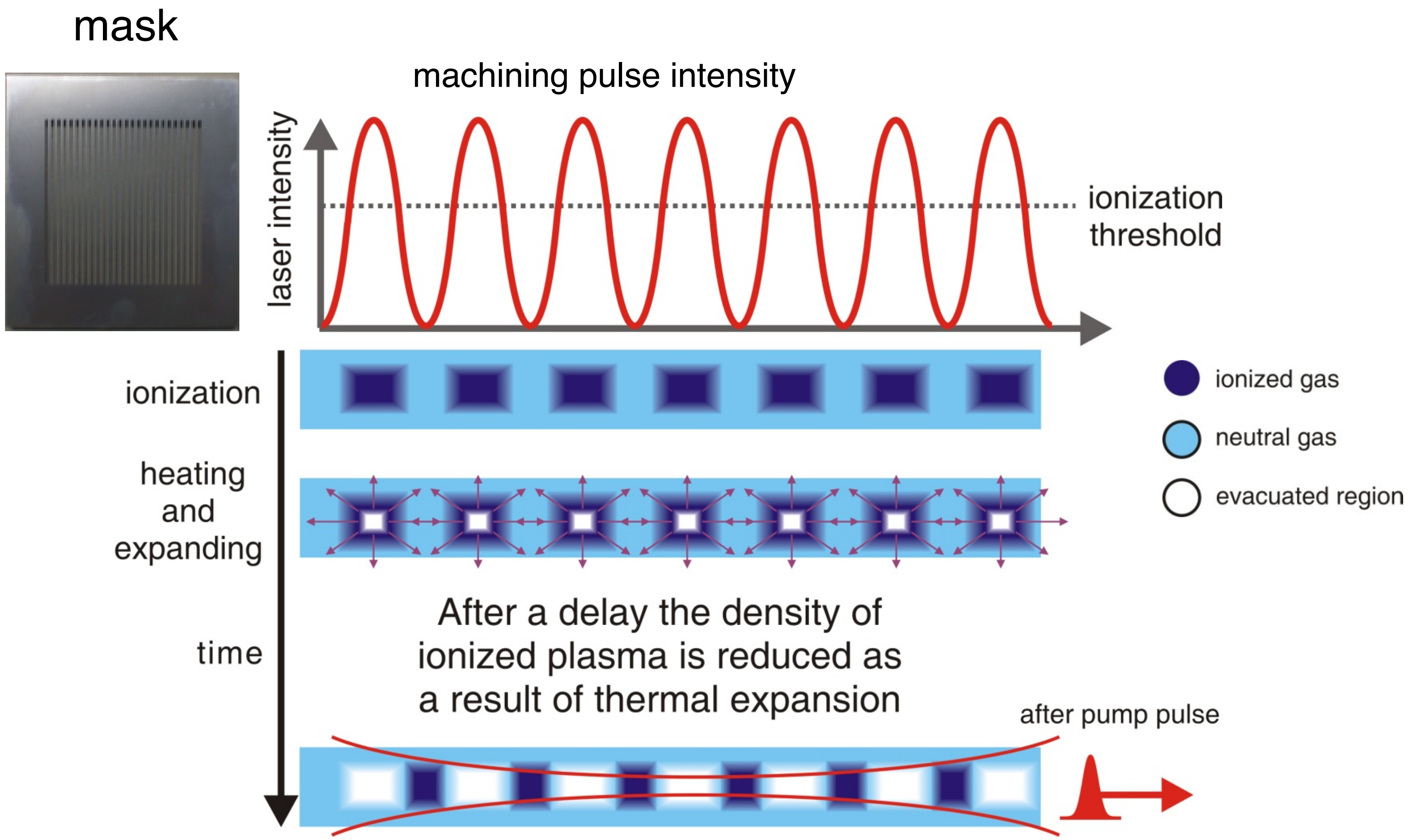
Step 2: The hot plasma expands. The density of the irradiated region is reduced.



Step 3: The pump pulse ionizes the rest of the gas and interacts with a plasma well.

Phys. Plasmas **11**, L21 (2004)
Phys. Rev. Lett. **94**, 115003 (2005)

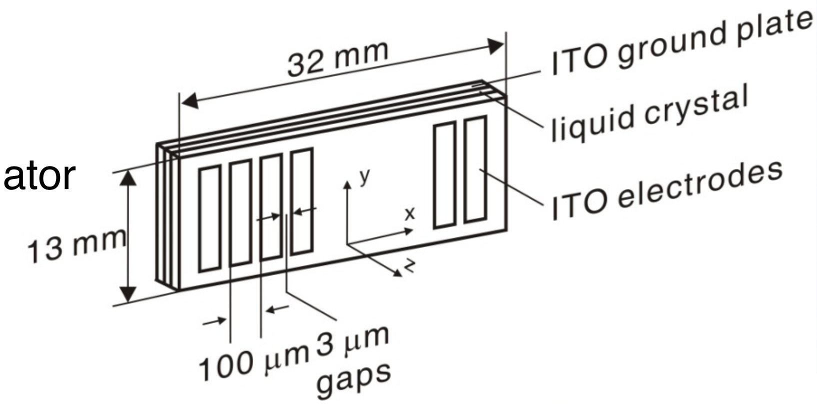
Fabrication of transient periodic plasma structures

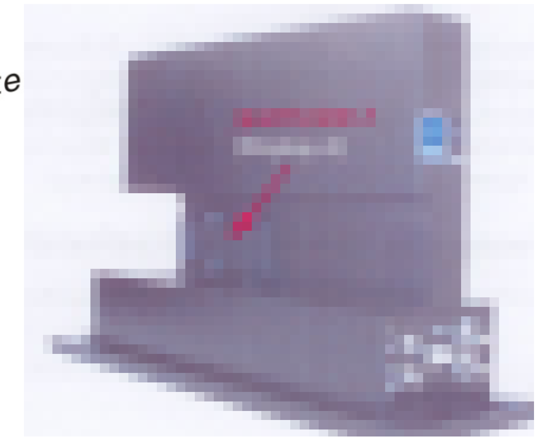


- The machining pulse plays both the roles of ionizing the gas through optical-field ionization and heating the plasma by above-threshold-ionization heating and inverse bremsstrahlung heating.

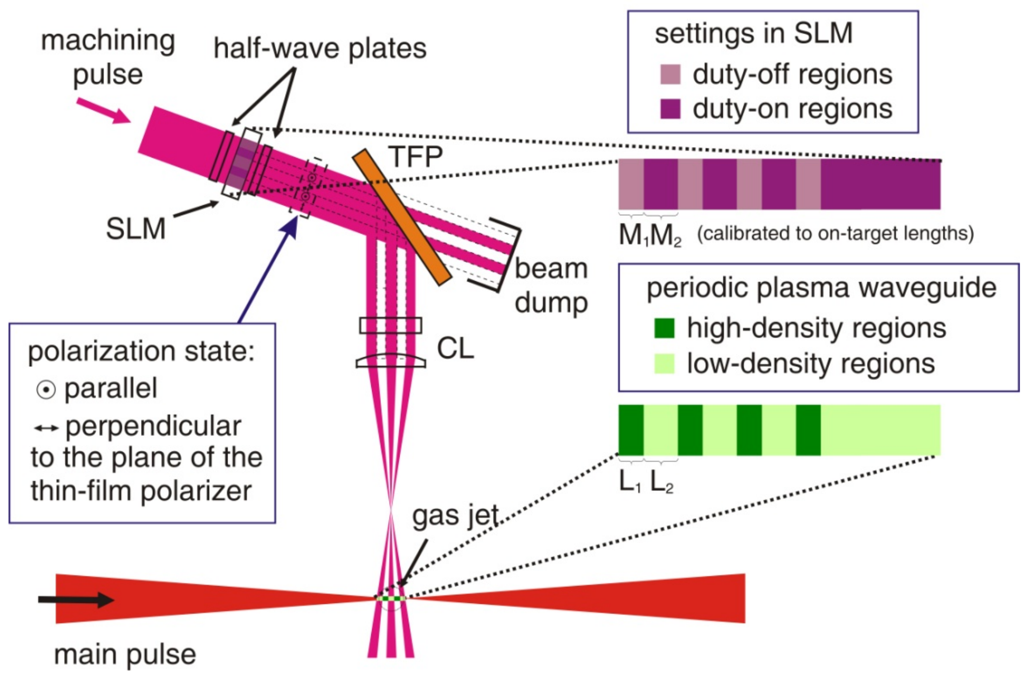
Programmable spatial amplitude modulator

liquid-crystal
spatial light modulator





Jenoptik
SLM-S320



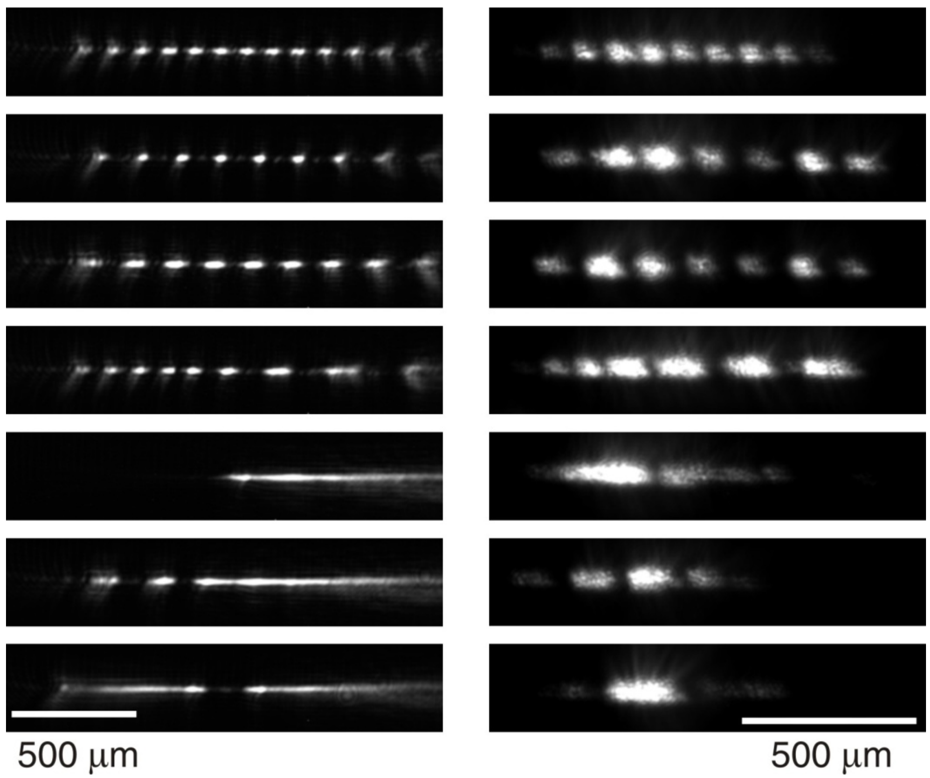
Programmable fabrication of arbitrary structures

intensity patterns set with a spatial light modulator

side scattering images

atom density: 3.2×10^{18} cm^{-3}

pattern parameters



duty-on region: 50 um
period: 100 mm

duty-on region: 50 um
period: 150 um

duty-on region: 100 um
period: 150 um

aperiodic pattern
period: 50 → 300 um

blocking half

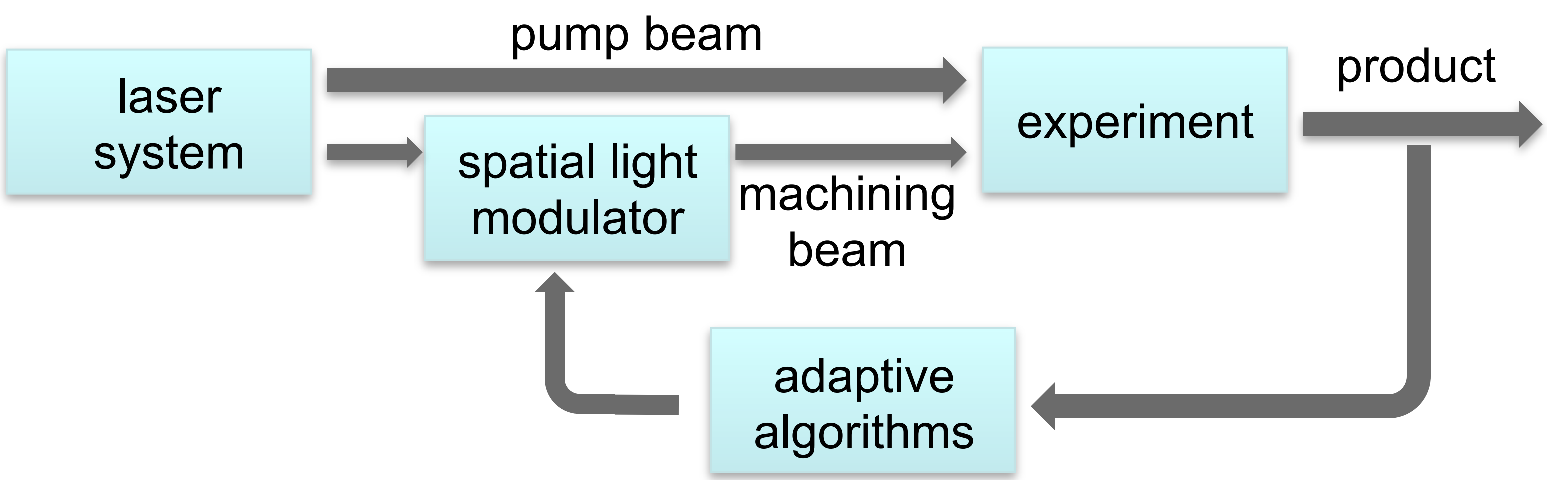
on after the third period

a well of 200-um width

Structures with features about 10um can be fabricated

Density range: 10^18cm-3 to 10^20cm-3

Adaptive feedback optimization of products



- By using the voltages of the SLM strips as the control parameters, in a way similar to adaptive feedback optimization of laser temporal waveform for quantum coherent control, adaptive optimization of the gas/plasma structure to enhance the products as well as their downstream applications can be achieved.
- Once the optimal plasma structure is obtained, it can be implemented in a simulation to find out the mechanism of enhancement.

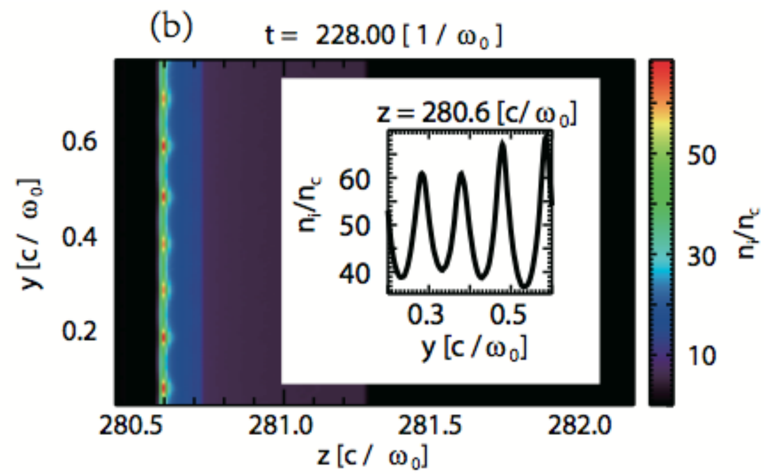
Proposed Experiment with current ATF parameters

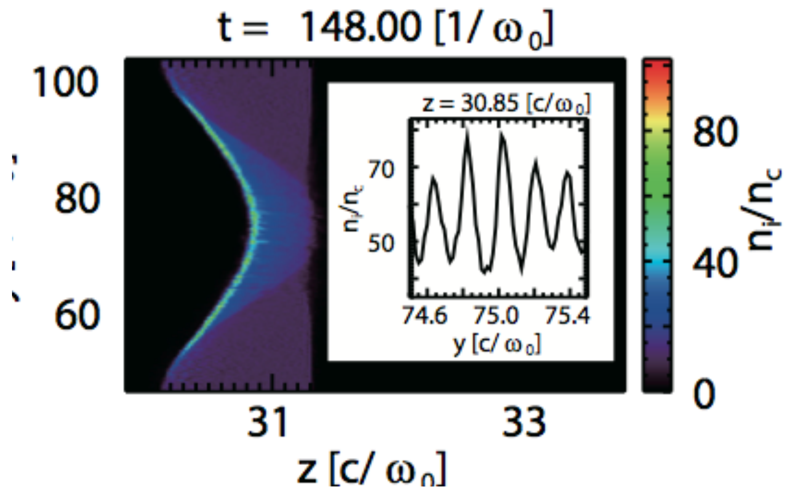
- Study of laser radiation pressure acceleration (RPA) of ions with very thin gaseous plasma target (10-50um)

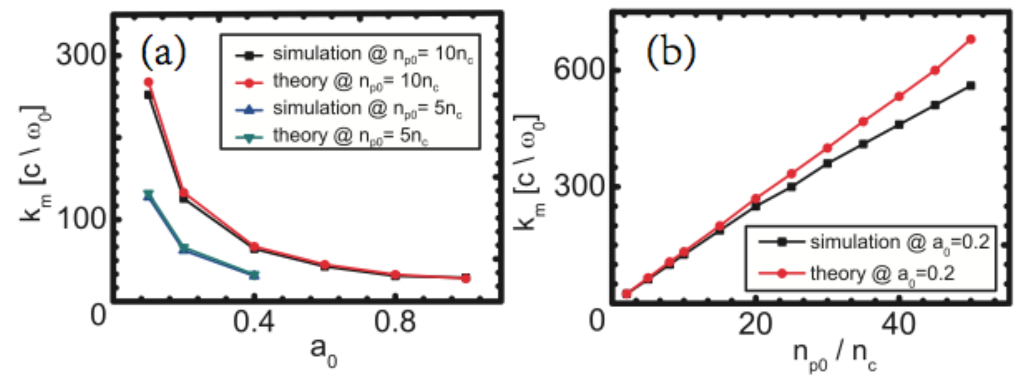
In about 1-2years to implement this tech at ATF, first may try with a CO2 prepulse as the machining pulse, later with 800nm laser of 10mJ or more energy

- Study of the transverse instability of RPA (recently a theory model has been developed to describe this important instability)

A new theory for RPA transverse instability







To be published

FIG. 2. (a) The relationship between k_m and a_0 when $n_{p0} = 10n_c$ and $5n_c$. (b) The relationship between k_m and n_{p0} when $a_0 = 0.2$. Both indicates that our theory has good agreement with 2D simulation results.

The goal of this experiment

- To try the RPA ion acceleration in well controlled plasma condition (thin target): **circularly polarized laser pulse needed, 2-3ps 1TW laser is OK for this study, in the weakly relativistic regime**

- To observe the mode structure of the transverse instability and to compare with theory and simulation if possible

Summary

- Combining high power CO2 laser with laser machining gas target may open up many new interesting physics study of LPI with NCD plasma at ATF
- We propose to do thin target RPA physics study with current laser parameters, focusing on the ion acceleration feature and transverse instability physics

Thank you for your attention!