Towards spin-polarised electron beams from a laser-plasma accelerator

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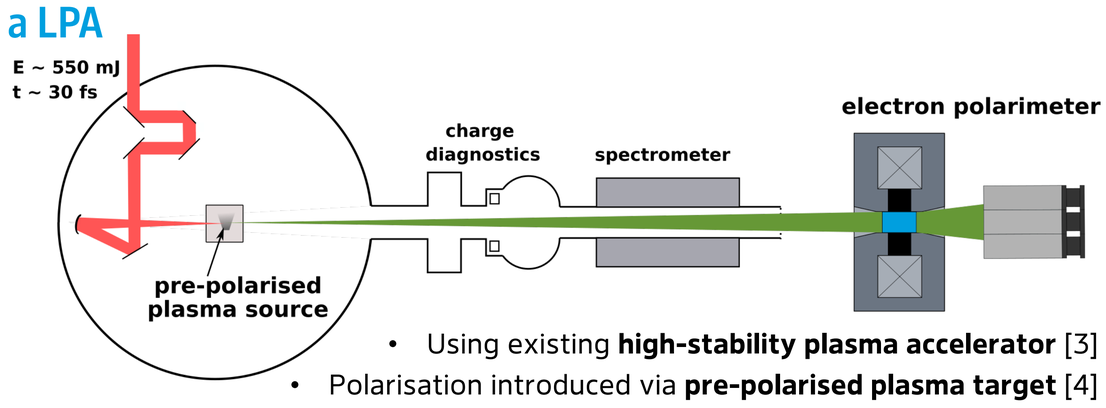
What makes polarised beams so interesting?

- Polarised beams are used extensively for
  - Particle physics
  - Nuclear physics
  - Atomic physics
  - Material science

$$P = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}$$

- Polarised electron beams can generate polarised photon and positron beams
- Longitudinal spin of main interest in high energy physics
- Polarisation also important in fusion [1,2]

LEAP: a proof of principle experiment for spin-polarised electrons from a LPA



- Using existing **high-stability plasma accelerator** [3]
- Polarisation introduced via **pre-polarised plasma target** [4]
- Polarisation measurement based on **Compton transmission polarimetry** [5]

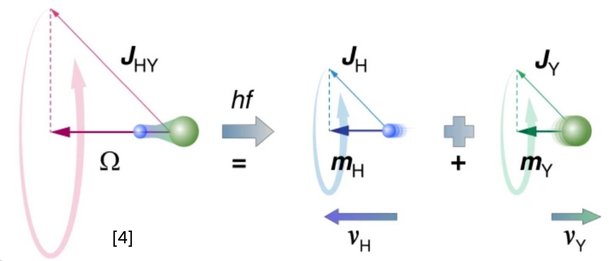
Concept of polarised LPA

Three step recipe:

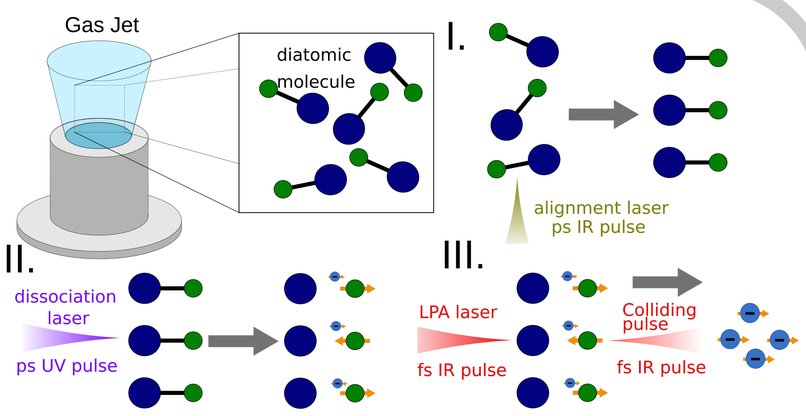
I. Align bonds of diatomic molecules with a linearly polarised IR pulse

II. Photodissociation with circularly polarised UV pulse

III. Colliding pulse injection and acceleration



[4]



- Total angular momentum projection quantum number preserved ➢ Polarised valence electrons
- From PIC simulations: Colliding pulse injection enables **P>90%** [6]

(Talk Kristjan Poder: 19.09.23 @ 17:45)

Key challenge: The dissociation

Choice of Gas

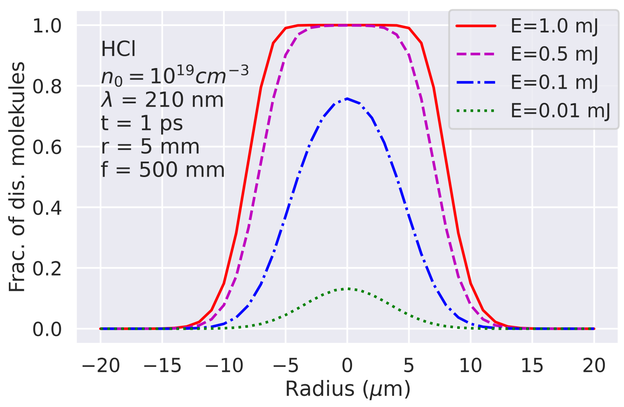
- Ionisable unpolarised electrons dilute polarisation

➢ **HCl** best choice for now (P->10%)

➢ Future option **H_2** (P->100%)

Gas	Pol. e-	Unpol. e- for $a_0 < 2$	Absorption cross-section @ 210 nm
HF	2	7	
HCl	2	15	6e-21 cm^2
HBr	2	23	7e-19 cm^2
HI	2	25	8e-19 cm^2

The dissociation laser



Requirements

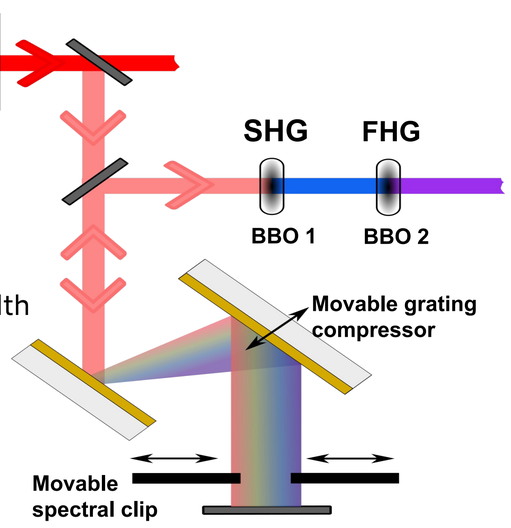
- Wavelength ~ **210 nm** [7]
- **Synchronised** to driver pulse
- ~ **1 ps** pulse length
- ~ **0.5 mJ** to fully dissociate a volume of the size of the plasma bubble ($\emptyset \sim 10\ \mu m$)

Generation from TiSa by cascading SHG

➢ Stretching UV pulse

➢ Maximising conversion efficiency (> **0.5%**)

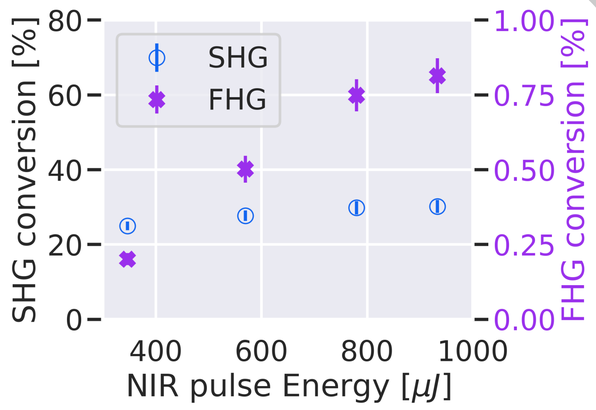
FH generation



FHG test setup:

- Energy control
- GDD control
- Control over spectral width
- Two BBO crystals

➢ Optimise FHG while not burning the crystals



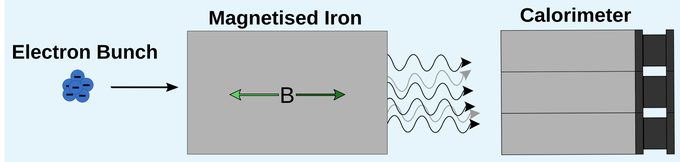
➢ Efficiency > 0.5% ✓

➢ Further optimisation

➢ Scaling to higher energies

Polarimetry of LPA electron beams

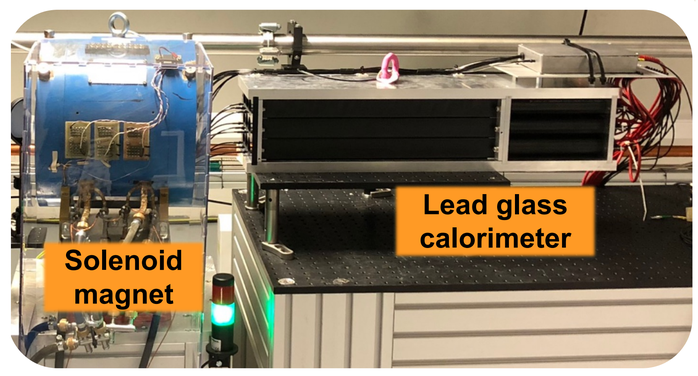
Transmission polarimetry



$$T \propto \exp(-n\, L_B\, \sigma_{pol} \vec{P}_\gamma \vec{P}_e -)$$

1. Polarisation dependent transmission of Bremsstrahlung through magnetised iron absorber
2. Photon detection

➢ **Polarisation proportional to transmission asymmetry**



- Polarimeter installed
- System test performed end of August

Next steps

- Demonstrating the dissociation of HCl [7] with TiSa-driven UV source
- Start to end simulations of LEAP ongoing:

  LPA + APL + Polarimeter
- Zero polarisation measurements in October
- Demonstration experiment

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