# Towards spin-polarised electron beams from a laserplasma accelerator

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DPG Spring Meeting, 23.03.2023



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#### HELMHOLTZ

### **Polarisation of an electron beam**

#### What makes it of special interest?

- Polarised particle beams are indispensable for many research fields
  - Particle physics
  - Nuclear physics
  - Atomic physics
  - Material Science
- Polarised electron beams can generate polarised photon and positron beams
- Longitudinal spin of main interest in high energy physics
- Polarisation also important in fusion [3,4]

[3] Temporal, M et al., Nucl. Fusion 52, 103011 (2012)[4] Hupin, G. et al., Nat. Commun. 10, 351 (2019)





### **LEAP project at DESY**



- Using our existing **high-stability plasma accelerator [5]**
- Polarisation will be introduced via a pre-polarised plasma target [6,7]
- The later polarisation measurement will be based on **Compton transmission Polarimetry**



Run duration (h)

50000

70000

10000

### **Concept of the pre-polarized plasma source**

### A three step recipe

- I. Align bonds of diatomic molecules with a linear polarised IR pulse
- II. Photodissociate the molecules with a circular polarised UV pulse
- III. Ionisation and acceleration through LPA driver pulse





- The dissociation preserves the total angular momentum projection quantum number
  - Valence electrons will be polarised
- The spin-polarisation will be transferred between the electrons and the nuclei on a timescale of 350 ps for H atoms

### **Concept of the pre-polarized plasma source**

### The Dissociation is a key challenge

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- I. Align bonds of diatomic molecules with a linear polarised IR pulse
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#### Plan to use **colliding pulse injection**: **S. Bohlen et al., in preparation**

 $v_{\rm H}$ 



The spin-polarisation will be transferred between the electrons and the nuclei on a timescale of 350 ps for H atoms

VV

### **Key challenge: The dissociation**

Choice of gas is crucial for the overall polarisation

- Has been shown for hydrogen halides @ ~ 210nm [8]
- Hydrogen halides contain many easily ionisable unpolarised electrons

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

- Unpolarised electrons delute the overall polarisation
- HCl best choice for now (P~10%)
- Future option  $H_2$  (P~100%)

[8] Sofikitis, D. et al., Phys. Rev. Lett. 121, 083001 (2018)

### **Key challenge: The dissociation**

### **TiSa driven UV source for LEAP**

#### **Requirements**

- Wavelength ~ 210 nm
- Synchronisation with the LPA driver pulse
- > 1 ps pulse duration
- ~ 0.5 mJ energy to fully dissociate a gas volume the size of the plasma bubble (~ 10 μm)

## At LEAP the UV pulse will be generated from TiSa by cascading SHG using two BBO crystals

- Need to stretch the generated UV pulse
- Maximising the FHG conversion efficiency (  $\sim 1 \%$  )



[9] A. Spiliotis et al., Chemical Physics Impact, 2 (2021) 100022.

### **FHG simulations**

#### Estimating the achievable conversion for a small scale setup

- Simulating the SHG and FHG in the wavelength range we are aiming for
- Here up to 60 % for SHG and 3 % for FHG are shown
- $\succ$  Measure efficiencies in the laboratory

 $\frac{\text{Simulation parameter}}{\text{E} = 1 \text{ mJ}, \text{ r} = 2.5 \text{ mm}}$  $\theta_{\text{SHG}} = 28.36^{\circ}, \text{ L}_{\text{SHG}} = 0.5 \text{ mm}}$  $\theta_{\text{FHG}} = 82.56^{\circ}, \text{ L}_{\text{FHG}} = 0.75 \text{ mm}}$ 



### Test setup in the laser lab

#### For conversion efficiency optimisation



- Beam pick-off from the main TiSa laser with full energy control
- Grating compressor with spectral clip
  - Full control over GDD
  - Control over the spectral width
- Two BBO crystals in place

#### <u>Tasks:</u>

- Detecting the FHG signal
- Parameter scan to optimise the conversion efficiency



### **Next steps**

#### Toward the pre-polarised plasma source





- Optimising the conversion efficiency for FHG
- Demonstrating the dissociation of HCl with a TiSa-driven UV source
- Stretching the generated UV pulse to ps length to avoid ionisation
- → Measuring the dissociation [8]

### Summary and status of the LEAP project

- LEAP: Demonstration of polarised electron beams from a LPA
- Using existing high-stability plasma accelerator
- Polarised beams through a prepolarised plasma source
  - Key challenge: The dissociation of HCl molecules
  - Ongoing work: Generation of UV pulse by cascading SHG
  - Colliding pulse injection
- **Compton transmission polarimeter** for the polarisation measurement
  - Under construction
  - Zero polarisation measurement planned end of April



t ~ 30 fs



## Thank you

#### Contact

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### **Polarimeter for LEAP**

#### **Compton transmission polarimetry**

- The magnitude of the asymmetry with respect to the magnetization direction is proportional to the photon polarisation.
- The value we have to measure in the experiment is the photon energy sum





$$\delta = \frac{\bar{E}_{AP} - \bar{E}_P}{\bar{E}_{AP} + \bar{E}_P}$$
$$P = \frac{\delta}{\text{analyzing power}}$$

### Laboratory

Lab Overview

