Modelling of electro-optic sampling for the study of laser-wakefield acceleration

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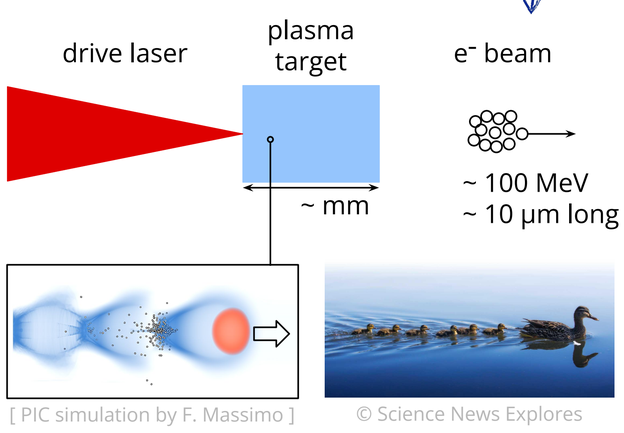
-0- Introduction

Electro-Optic Sampling (EOS) = tool to measure **time of arrival** and **longitudinal profile** of e- beam generated with laser-wakefield accelerator (**LWFA**)

Applications:

+ improve stability of the source (gas cell or gas jet)
+ multi-stage acceleration

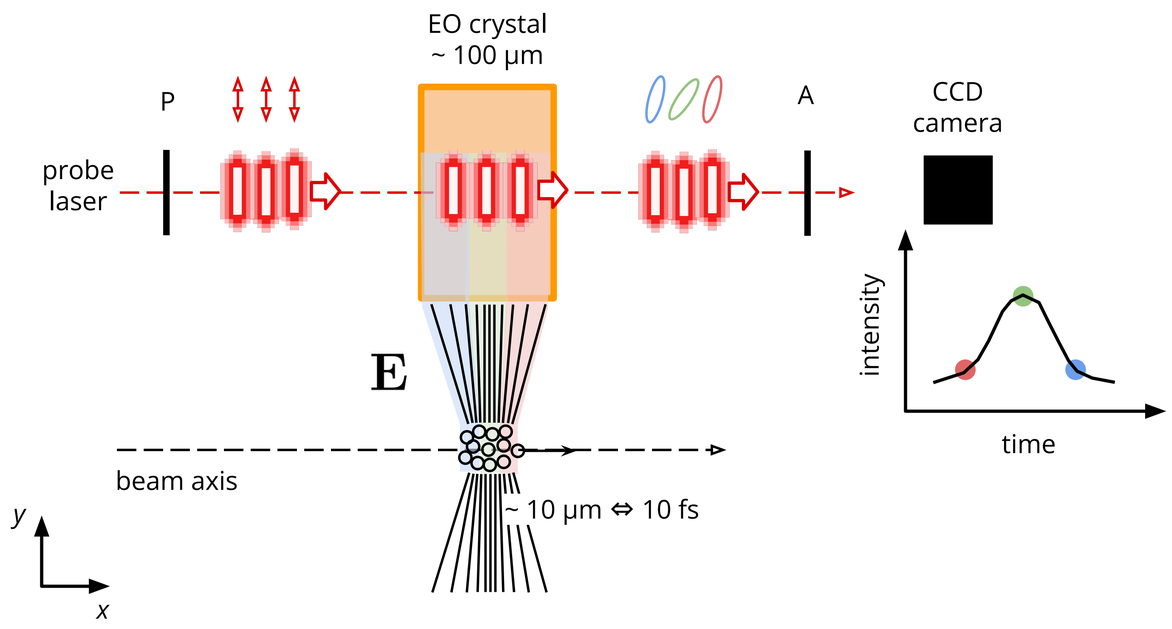


[PIC simulation by F. Massimo] © Science News Explores

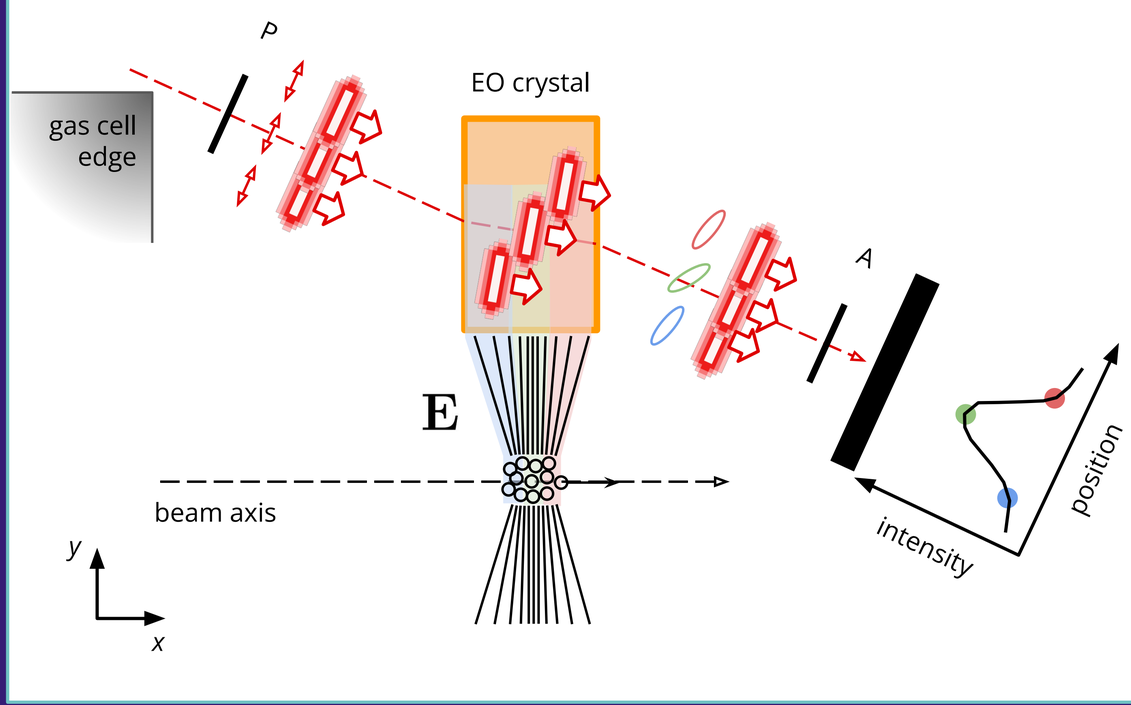
-1- EOS working principle

Ref: [1-3]

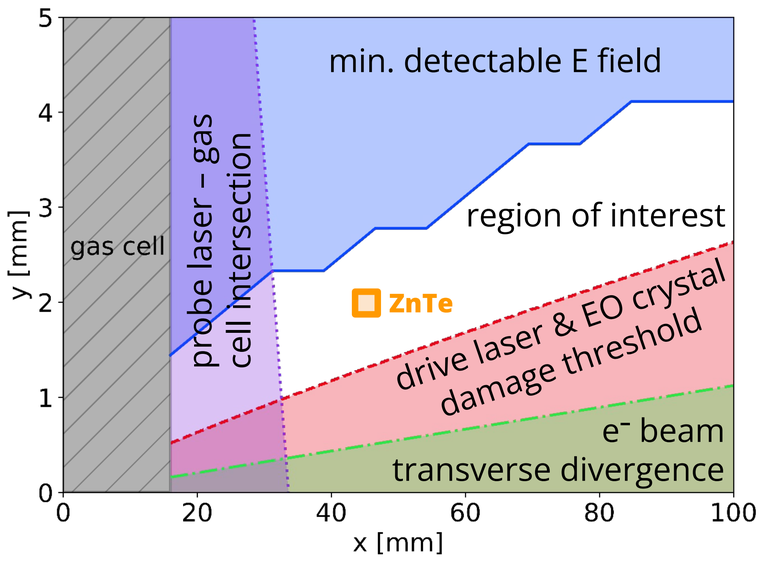
Main idea: imprint electron beam profile on probe laser inside EO crystal: isotropic → anisotropic in **E**



Remark: cameras with ~fs speed do not exist ⇒
Temporal → Spatial decoding



-2- Experimental constraints

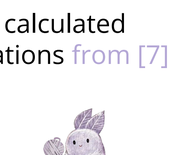


EO crystal (ZnTe) damage threshold = 38 mJ/cm² from [4]

Laser and e⁻ beam parameters from [5]

Probe incident angle = 44 degrees from [6]

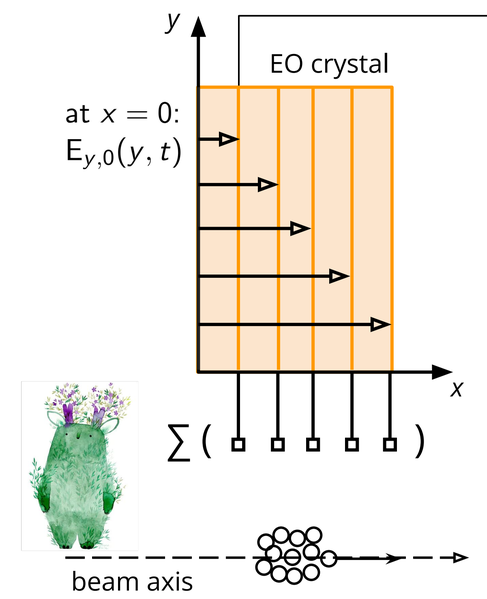
Min. detectable E field calculated according to considerations from [7]

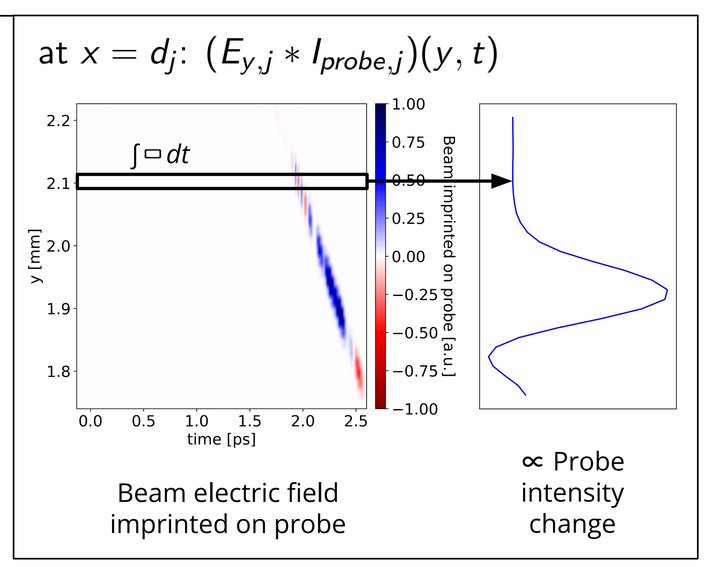


-3- Numerical Modelling

Ref: [1-3,8]

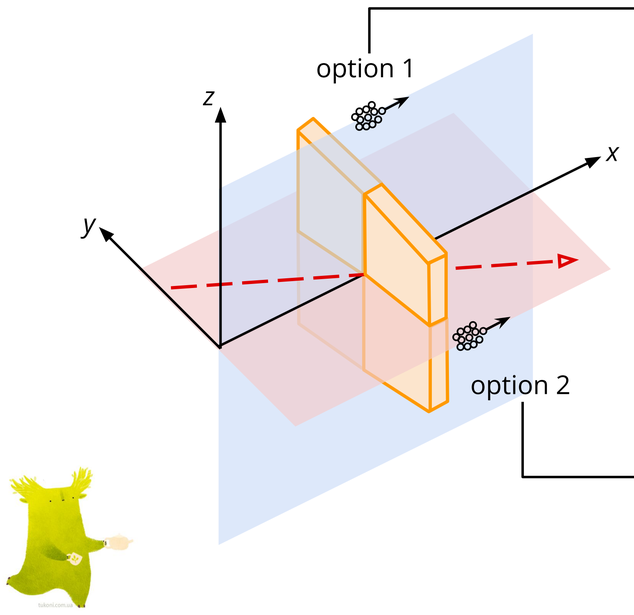
Remark: for simplicity, fix z and later repeat for all z to get (y,z) image on camera >> see "Results"

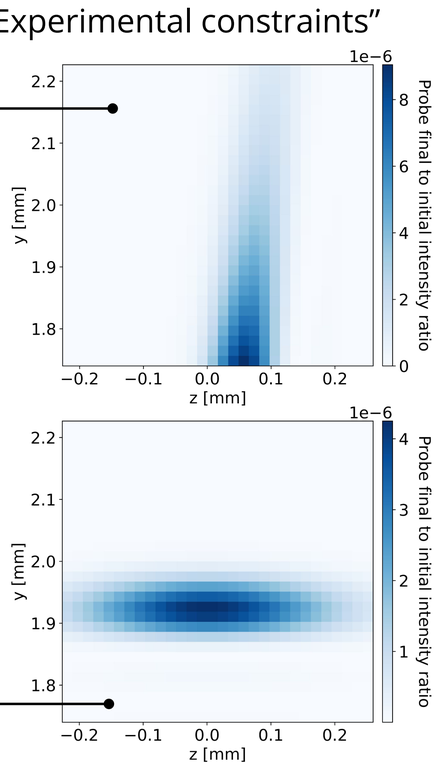




-4- Results

Probe laser impinges EO crystal at ZnTe >> see "Experimental constraints"
Crystal thickness: 200 µm
Probe laser: 800 nm, 28 degrees





-5- Applications of EOS modelling

WE ARE HERE

EO crystal: material, thickness, position
Probe laser: angle of incidence
tune*
expected e⁻ beam → EOS modelling → I(y,z) on camera

⇒ Best crystal & probe parameters

Input data set of e⁻ beams → EOS modelling → Output data set of I(y,z) on camera
ML algorithm

⇒ (EOS modelling)$^{-1}$ for **BEAM RECONSTRUCTION**

*Taking experimental constraints into account >> see "Experimental constraints"

-6- Conclusions

Electro-Optic Sampling (EOS) is a well-known technique for conventional accelerators. Given ~10^3 times shorter beams obtained with LWFA, EOS needs to be adjusted.

By using the methods described in this poster, we are **designing an EOS setup**.

It will be implemented experimentally to **study the stability** of LWFA electron beams in gas cells. Moreover, experimental data will be used to **verify** if the EOS modelling is working correctly and to **improve** it, if necessary.

Finally, we aim to develop a **beam reconstruction algorithm** for the experimental data analysis.

References:
[1] R. Pompili, PhD thesis
[2] B. Steffen, PhD thesis
[3] S. Casalbuoni *et al.*, PRSTAB 11 (2008)
[4] H. Sun *et al.*, Optical Materials 160 (2025)
[5] S. Marini *et al.*, PRAB 27 (2024)
[6] K. Huang *et al.*, Sci. Rep. 8 (2018)
[7] K. Huang *et al.*, PRAB 22 (2019)
[8] K. Huang *et al.*, PRAB 26 (2023)

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