Sub- picosecond Electro- Optic Detection of a Charged Particle Beam

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OUTLINE

1. Motivation
2. Electro–optic effect
3. Experimental Aparratus
4. Measurements
5. Future – Summary

MOTIVATION

- Sub–ps temporal resolution

- Non Destructive measurement

Electro–optic Effects

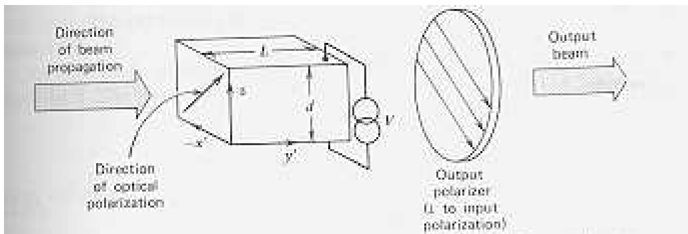


FIGURE 14.7 A transverse electrooptic amplitude modulator using a KH_2PO_4(KDP) crystal in which field is applied normal to the direction of propagation.

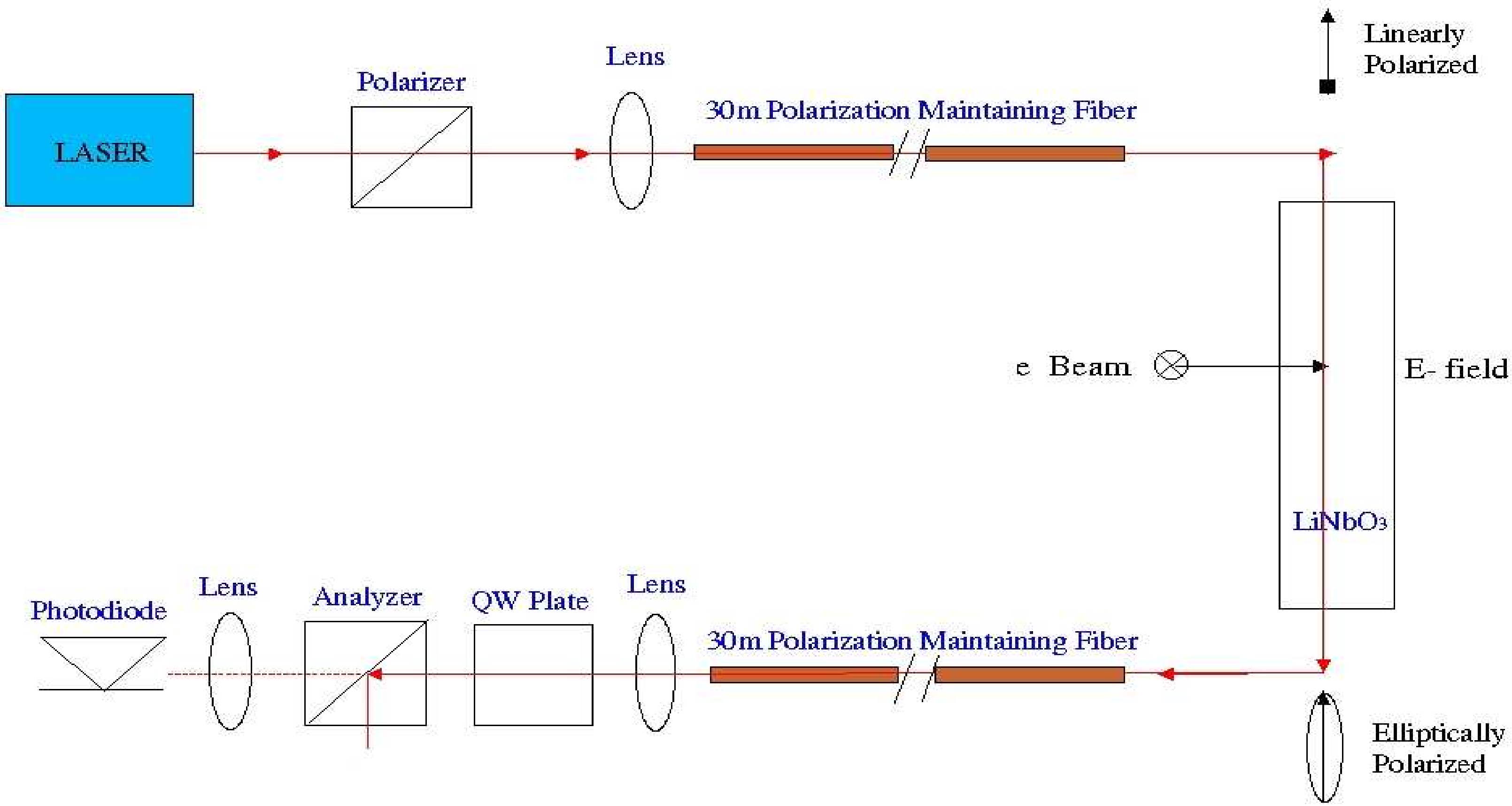
- Quadratic–Kerr Effect: $\phi = \dfrac{2 \cdot \pi}{\lambda} \cdot K \cdot E^2 \cdot d$

K=Kerr coefficient (nitrobenzene $2.4 \cdot 10^{-12} m/V^2$ @589nm)

- Linear – Pockels Effect: $\phi = \dfrac{2 \cdot \pi}{\lambda} \cdot P \cdot E \cdot d$

P=Pockels coefficient ($LiNbO_3$ $P_{33} = 3.3 \cdot 10^{-10} m/V$ @633nm)

Experimental Setup



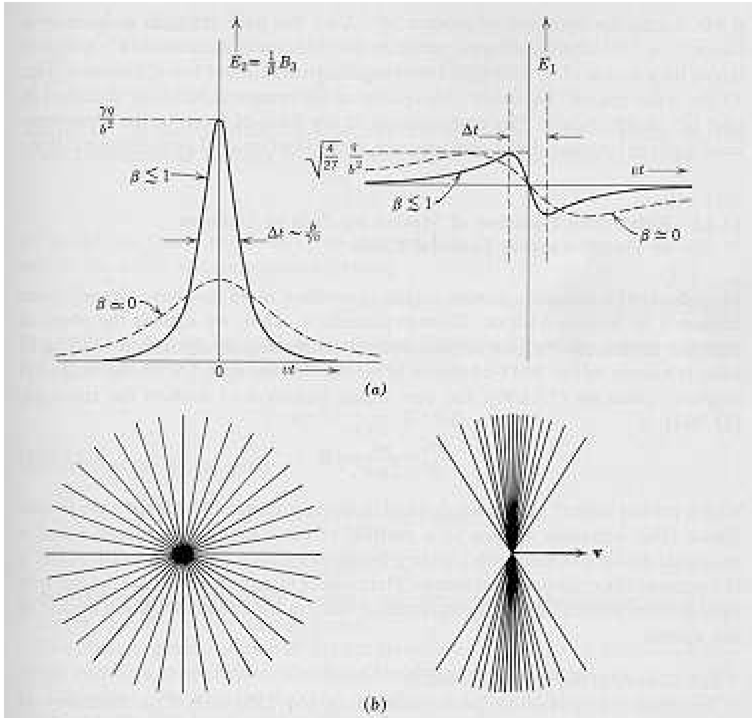


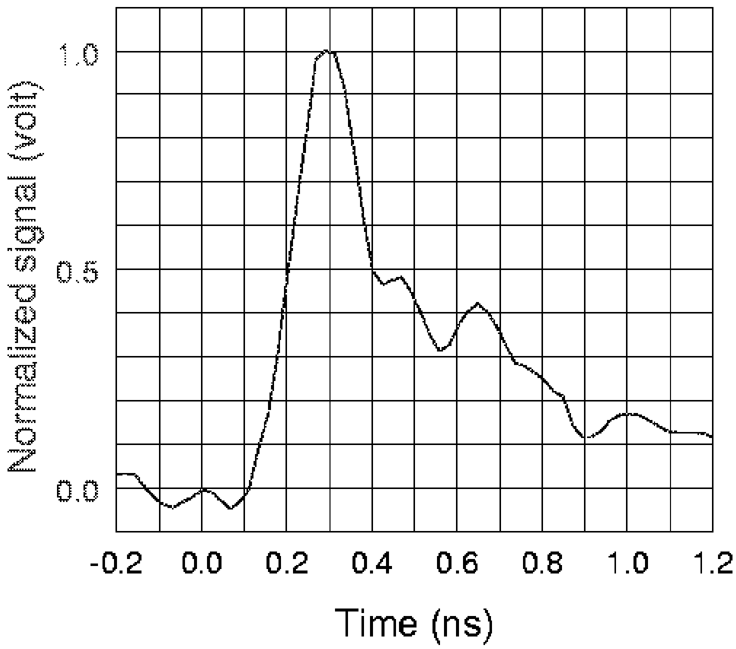
Fig. 11.9 Fields of a uniformly moving charged particle. (a) Fields at the observation point P in Fig. 11.8 as a function of time. (b) Lines of electric force for a particle at rest and in motion ($\gamma = 3$).

- E–Field from a charged particle beam :

$$E = \gamma N_e \frac{q}{(4\pi \varepsilon r^2)} \quad \text{for} \quad \Delta t = \frac{r}{(\gamma c)}$$

e.g. For r=5mm $E = \gamma \cdot N_e \cdot 10^{-5}\, V/m$, $\Delta t_1 = \frac{17}{\gamma} ps$

Measurement at ATF 05/1998



- 20 mW of CW laser at 1320nm
- 10^{10} electron pulse beam, 10ps long, 1mm diameter at 1.5 Hz from ATF of BNL
- 45 GHz BW photodiode + 7GHz transient digitizer
- Corresponds to ~10% modulation
- ~120ps rise time , single shot (limited by the Oscilloscope)

Future Plans

- Development of a compact, vacuum compatible setup optimized for EO detection

- Methods for ps and sub–ps sensitivity:

1. Single Shot, using Streak Camera

2. Autocorrelation

3. FROG

4. Signal Sampling with a fs pulsed laser

1. Single Shot, using Streak Camera

Availiable at ATF: C1587 Hamamatsu Streak camera
Range 200–850nm and 2–10ps resolution time

We Have : Omnichrome Argon cw laser at 514.5nm
(50mW)

Assuming a factor of 5 optical losses and the same
~10% EO effect we saw at ATF

We have with the above laser
~3000 photons/pulse/ps

We Would Need : Synchroscan FESCA (C6860)
Hamamatsu Streak Camera with 500fs Temporal
resolution (~210k $)
or
FESCA–200 (C6138) Hamamatsu Streak Camera
with 200fs Temporal resolution (~250k $)

Summary

- Simple and non destructive

- 120ps rise time, single shot (limited by electronics)

- currently working on 2ps resolution time
  (Next goal)

- sub−ps
  - Streak Camera with sub−ps resolution
    (Not availiable)
  - FROG
  - Autocorrelation