Detection of DC electric field using electro-optical crystals

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Introduction

Standard Beam Position Monitors (BPM) are intrinsically insensitive to beams with no temporal structure, so-called DC beams, which many CERN experiments rely on. We therefore propose a novel detection technique in which the usual BPM electrodes are replaced with electro-optic (EO) crystals. When exposed to an electric field, such crystals change their optical properties. This can be exploited to encode the electric field magnitude onto the polarisation state of a laser beam crossing the crystal. An additional EO crystal, placed outside the vacuum chamber, can be used to control the system's working point and to introduce a sinusoidal modulation, allowing DC measurements to be performed in the frequency domain. This contribution presents the working principle of this measurement technique, analytical results for a double-crystal optical chain and the experimental data taken on a laboratory test bench.

Electro-Optical DC field sensor

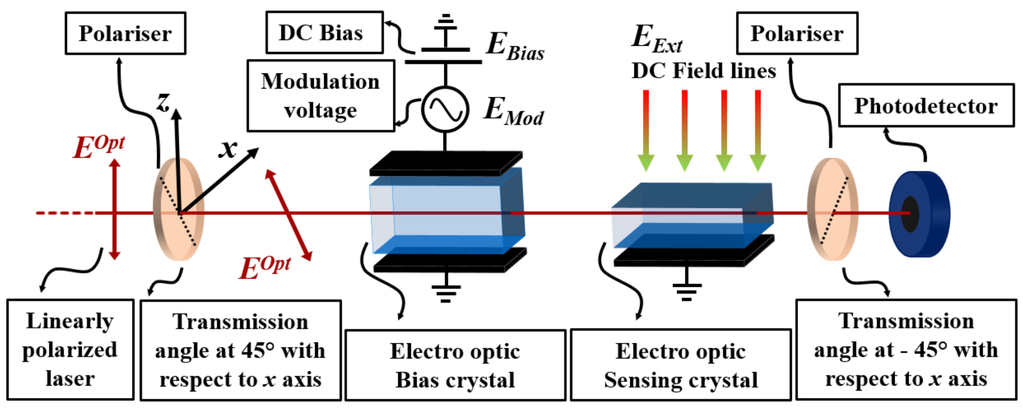
Detection technique

- Field intensity encoded in a laser beam through an **electro-optical** crystal exploiting **Pockels effect**
- Time varying modulation to perform the measurement in **frequency domain**

Advantages

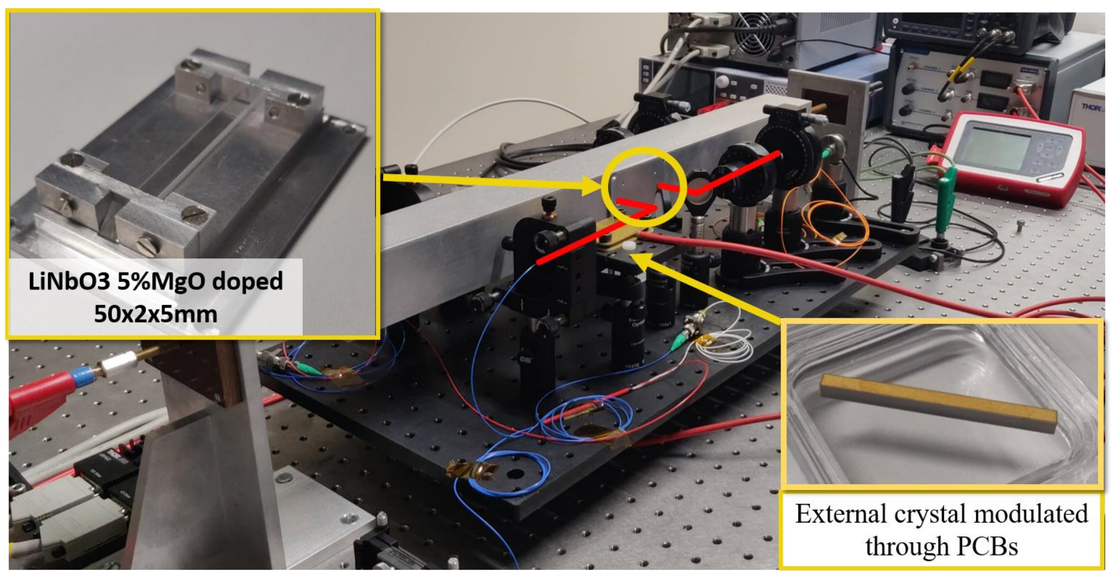
- **Non-destructive** coupling to the beam's DC field
- **Space-charge and temperature** dependence compensation
- Compatibility with the accelerator environment
- Optical-fibre-based signal transmission

Analytical model

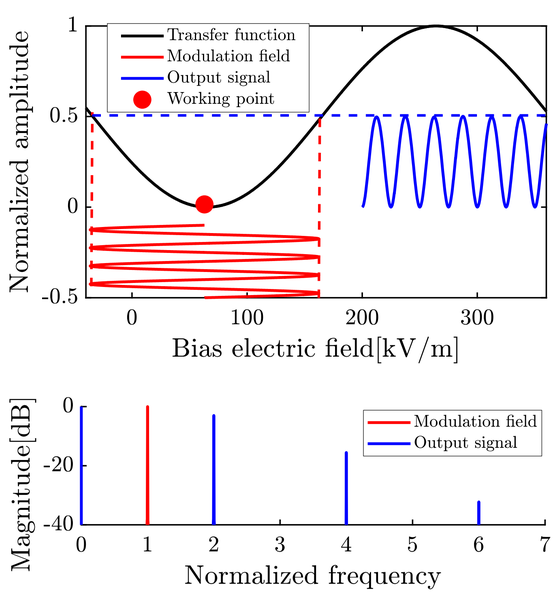


- **Modular structure** implemented in MATLAB
- **Good agreement** with experimentally measured transfer function
- **Temperature dependence** based on experimental data

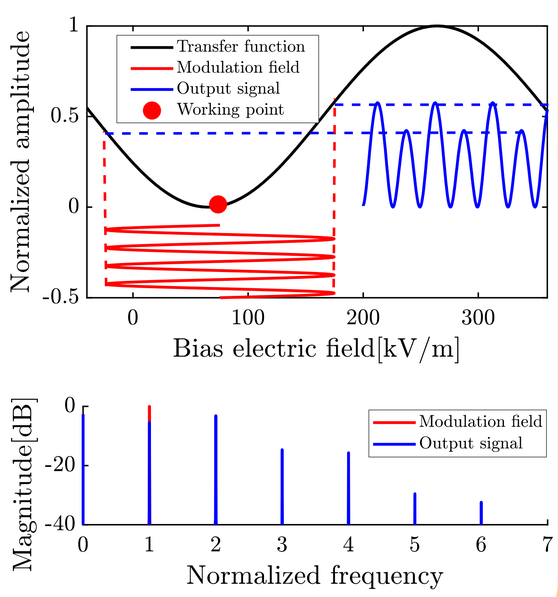
Laboratory test bench



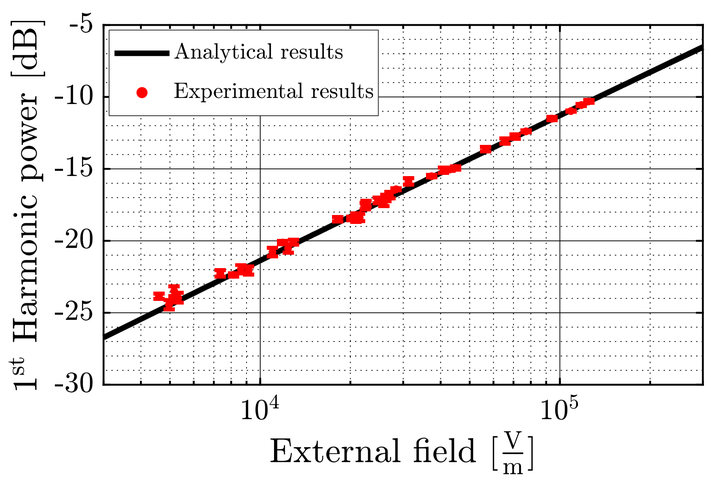
Centered beam



Off-centered beam

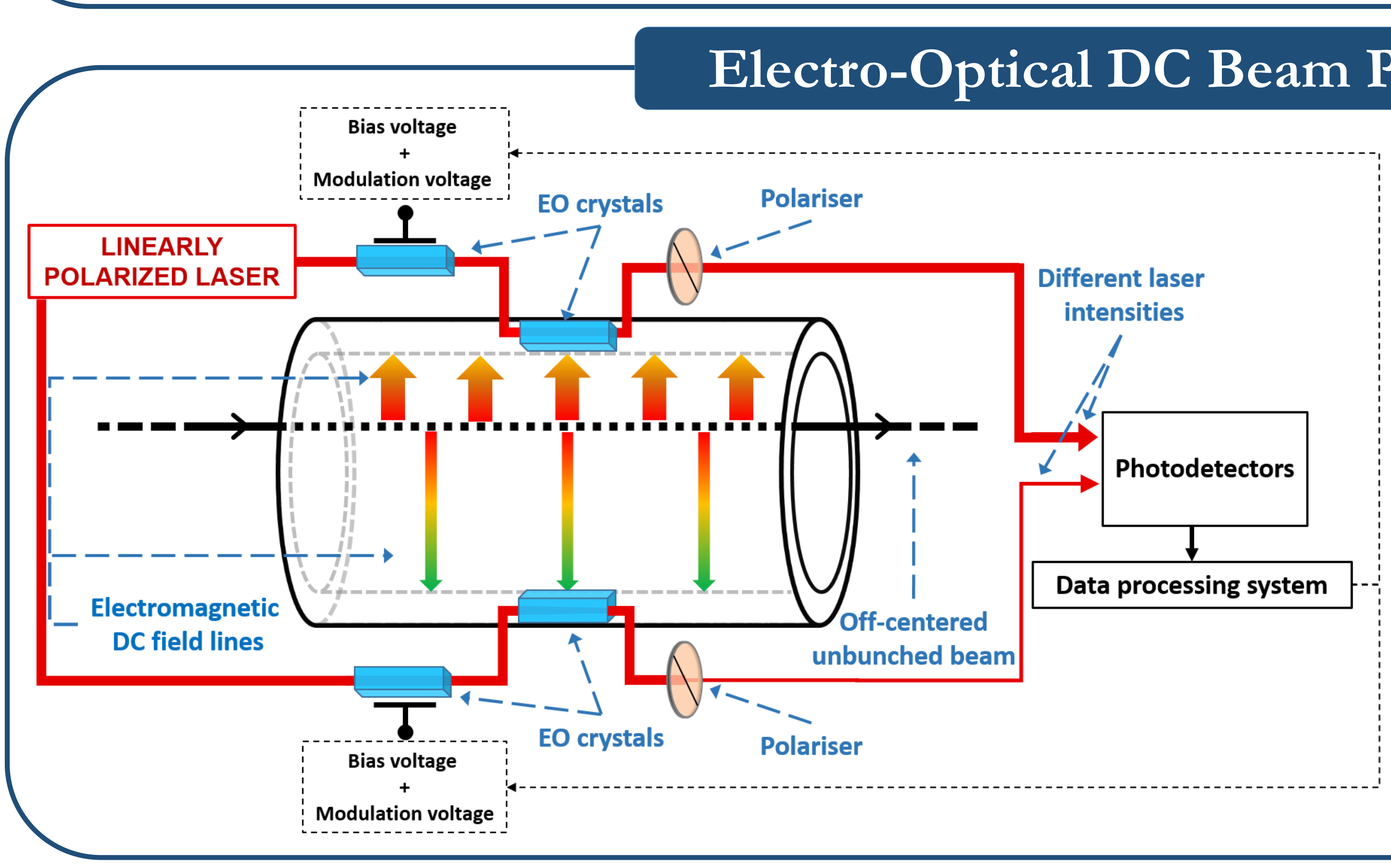


Experimental results



- **3 to 150 kV/m** electrostatic field intensities measured
- **90 V/m** resolution with a limited dynamic range (30 dB) for measuring the first harmonic

Electro-Optical DC Beam Position Monitor



Analytical estimation of the resolution

DAQ	I_b [A]	BW [Hz]	R* [mm]	DR [dB]	Position resolution [μm]
scope	2.8	59	45	30	3e3
custom	2.8	100	45	75	0.1
custom	0.28	100	45	75	1
custom	0.28	100	80	75	2.5