Laser calibration system for the CERES TPC (preliminary)

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January 16, 1998

1 Task

The purpose of the laser system is to generate narrow light beams at known positions (resolution 200 μm) and times (resolution 10 ns) in the sensitive volume of the TPC. These beams will be used to simulate charged particle tracks in two applications:

Calibration The response of the TPC to tracks at different position and at different values of the magnetic field will be used to verify the knowledge of the electric and the magnetic fields, and to test the tracking routines (after they are adapted to worked for tracks parallel to beam).

Monitoring During data taking, the laser system will generate low-rate events which will go on tape in parallel with the physics events. This will enable us to monitor changes of the TPC behavior during experiment.

2 Concept

An ionization similar to the one caused by fast charged particles can be achieved using low divergence ($<$ 0.5 mrad), low diameter (2 mm) laser beams with 266 nm wavelength, pulse duration of several nanoseconds, and beam energy of 10-20 μ J per pulse. The ionization occurs via two-photon absorption and thus transverse distribution of the ionization density is in every direction $\sqrt{2}$ times narrower than the light intensity distribution. Another consequence of the two-photon absorption is that the intrinsic fluctuations of the laser intensity will propagate squared to the ionization.

We decided to use a Nd:YAG laser (1064 nm) with two frequency doublers resulting in a 266 nm beam. After some optics (intensity control, circular polarization and telescope), the laser beam will be transported to the accelerator beam axis and then upstream up to 4 cm before the downstream surface of the aluminum backplate of the TPC (Central Distribution Point) using two partially (90%) reflecting remotely controlled mirrors MIR 1 and MIR 2 (see Fig. 1). The beam position will be monitored using two x-y position sensitive diodes placed directly behind the mirrors. At the Central Distribution Point the beam will be either reflected or splitted, resulting in one or several beams perpendicular to the accelerator beam axis and parallel to the TPC backplate. These beams will pass through two or more partially reflecting mirrors which will send part of the light into the TPC through two quartz windows. The remaining light will hit a x-y position sensitive diode. The position information from this diode, combined with the position informations from the main beam diodes and the reflection angle of the last mirror, will be used to calculate the laser beam position in the TPC for every pulse. No additional measurement of the beam position at the other end of the TPC is necessary.

The concept assumes that two mirrors will stay in the accelerator beam axis. This is OK for the calibration phase. For monitoring, a mechanism will be provided to move the mirrors out of the beam during the spills. The laser will pulse only between the spills, probably shortly before or after the spill.

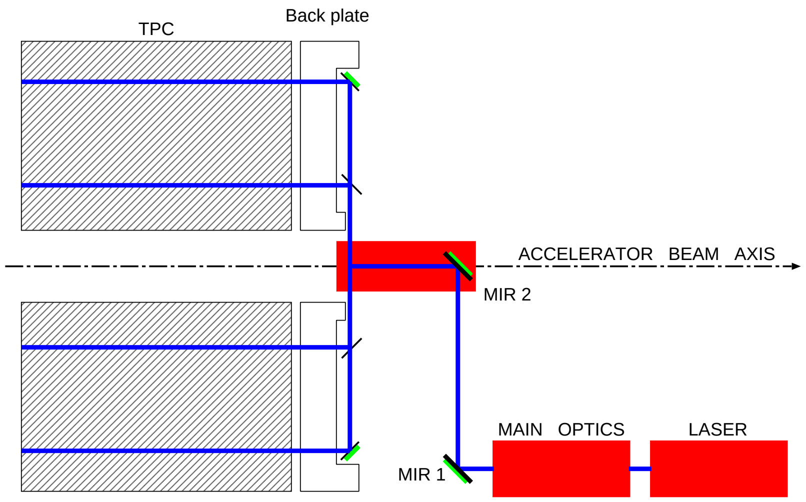

Fig. 1. Laser calibration system concept. The red elements (the intensity control, two bending mirrors and the splitter mirror) are remotely controlled. The green rectangles are the position sensitive diodes.

3 Detailed description

3.1 Laser

The laser is SL 401T Nd:YAG manufactured by Spectron Laser Systems [2] and purchased from Polytec [1]. The laser produces light pulses of about 4 ns duration and with adjustable frequency up to 10 Hz. The wavelength is 266 nm, the polarization horizontal, and the beam energy 6 mJ per pulse. The TEM_{00} aperture, located in the oscillator cavity, supresses all tranverse modes other than TEM_{00}. As a consequence, the transverse distribution of light intensity is narrow and gaussian. The beam diameter is 2 mm which corresponds to the σ of the gaussian of 0.5 mm. The laser has water cooling and requires external water supply. The operation is controlled from a PC via serial port.

3.2 Main optics

Directly after the laser, the beam goes through the intensity control optics which consists of a $\lambda/2$ plate, which rotates the polarization plane, and a polarizer. By rotating the $\lambda/2$ plate the polarization angle before the polarizer can be varied, and thus intensity of the light passing through the polarizer can be changed. The rotation of the $\lambda/2$ plate is remotely controlled. The rotary stage used for it, similarly as the splitter rotary stage and the two main mirror holders described below, come from New Focus [3]. They are controlled via the New Focus Picomotor Driver which is connected to the PC via a serial port.

Next, a $\lambda/4$ plate converts the polarization from linear to circular. Half of the intensity gets lost. The circular polarization lowers the danger that the future reflection coeffitients will depend on the direction of the reflection.

After that, a Galilean telescope is used to focus the beam such that it is narrowest in the middle of the TPC length.

3.3 Beam transport from the main optics plate to splitter

The last element on the main optics plate is a remotely controlled mirror which bends the laser beam towards the accelerator beam axis. A diode located behind the mirror monitors the beam position (see below). A similar mirror/diode combination, located on the accelerator beam axis, sends the beam upstream along the accelerator beam axis up to the Central Distribution Point which is located on the accelerator beam axis 4 cm downstream from the downstream surface of the TPC backplate.

3.4 Splitter

The TPC consists of 16 segments in ϕ. From the Central Distribution Point the light is reflected radially either by a rotating mirror to one of the segments at a time, or by a splitting prism (Pencil) simultanously towards 4, 8, or 16 segments (see Fig. 2). During the calibration phase the rotating mirror method will be used. For monitoring we may want to use the Pencil method. In both cases the optical element will be mounted on a remotely controlled rotary stage.

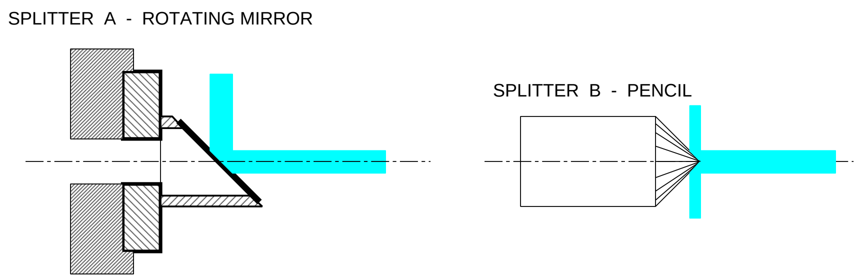

Fig. 2. Two possible methods of splitting the beam at the Central Distribution Point. Left: a rotating mirror sends the beam towards one TPC segment at a time. Rigth: a prism (Pencil) splits the light into 16 beams, one for each TPC segment.

3.5 Entrance to the TPC

Fifteen segments will have entrance windows for two laser beams (Fig. 3 left). The radially incoming laser beams will be reflected into the TPC by partially reflecting mirrors. The first of the two mirrors (r=800 mm) reflects 50%; the second (r=1200 mm) 90%. The rest of the light hits the diode located behind the second mirror. The mirrors are glued to aluminum holders which are mounted at well defined positions on the TPC backplate. Thus the positions and the inclination angles of the mirrors can not be changed. The r=1200 mm holders have diodes mounted on them.

The special segment, used for the calibration, will allow for additional laser rays (Fig. 3 right).

The reflected beams enter the TPC through 10 mm diameter holes in the backplate. The holes are closed by AR-coated quartz windows glued to the backplate from the TPC side. Another set of quartz windows is glued to the field cage foil which has 10 mm diameter holes to let the light through. The backplate and field cage windows have a thickness of 3 mm and 1 mm, respectively, and a diameter of 12.5 mm.

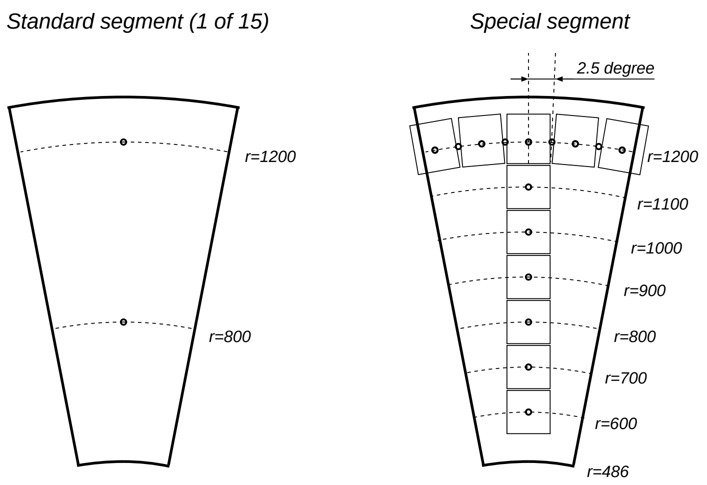

Fig. 3. The location of the laser beams in a standard segment (left) and in the special segment (right). The circles represent 10 mm diameter holes in the backplate and the field cage through which the laser beams will enter the TPC. The rectangles represent the mirror holders mounted on the backplate. The mirror holders on the r=1200 mm radius have diodes mounted behind the mirrors.

3.6 Diodes

We use Silicon Sensor diodes DL-100-7Ker, purchased from GIGAHERTZ-OPTIK GmbH [4]. The active area is 10×10 mm^2 and the position resolution better than 1 μm. Hit by a laser beam, each diode produces two cathode and two anode signals. The sum of amplitudes is proportional to the light intensity, and the difference between the two cathode (anode) signals is related to the position in x (y).

The signals are amplified, streched and digitized by the electronics (Fig. 4) which is located on two boards of 10×10 cm^2 each. The diode itself is mounted at the center of the first board.

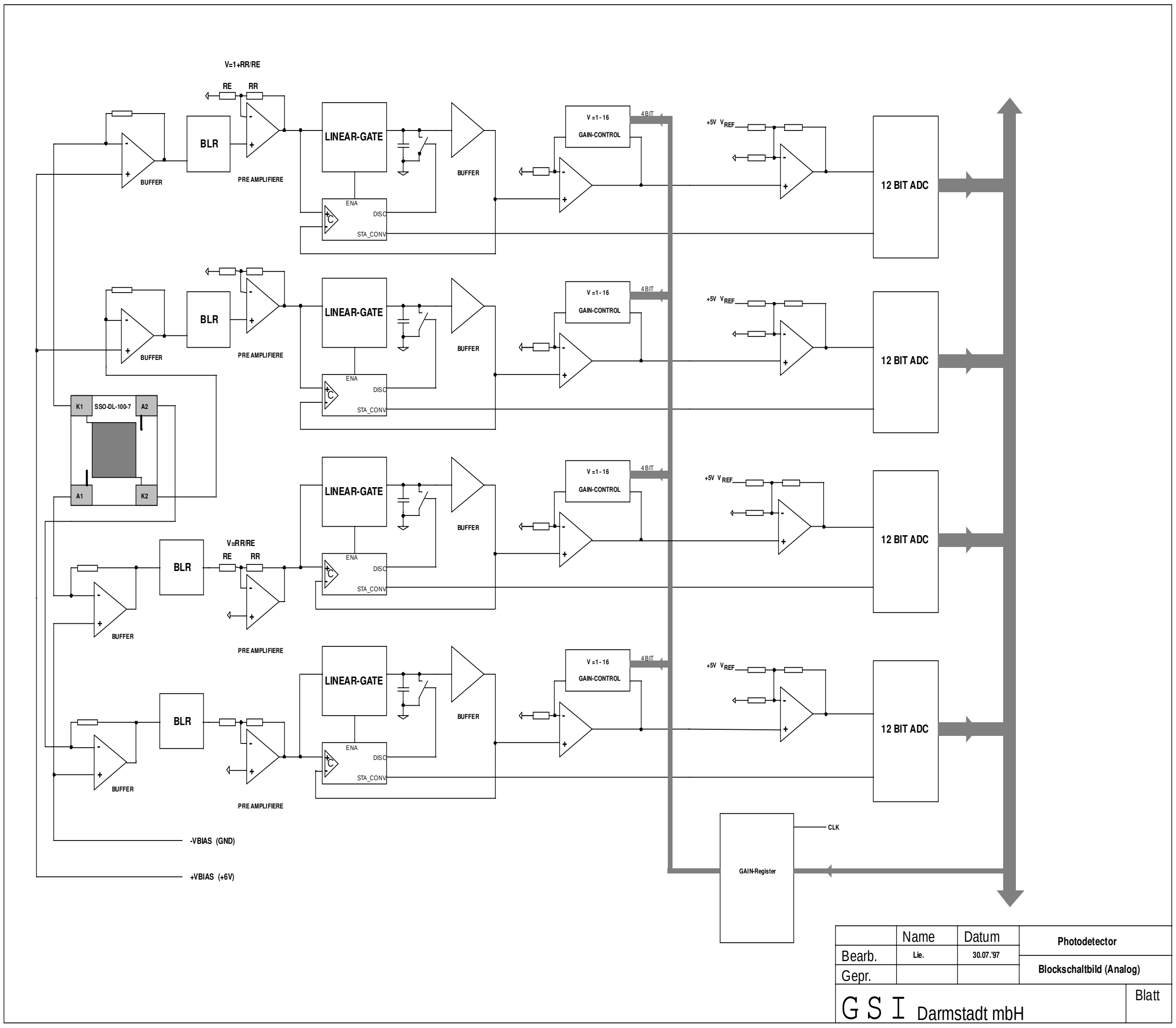

Fig. 4. Analogue part of the diode readout electronics.

The gain factor can be varied within a factor of sixteen. The ADC gate is generated for every channel in which the signal exceeds 50 mV. The digitized data is transported via a daisy chain to the LPT port (or to a special PCI card) of the PC (Fig. 5). The electronics comes from the Data Acquisition and Electronics Department of GSI (H-P. Liebold, J. Hoffmann).

3.7 Communication

A PC (Pentium processor 133 MHz, 32 MB memory, 2 GB hard disk, Ethernet card, 4 independent serial ports, 1 parallel port) running both under Linux and WIN95 (to choose during booting) is used to control the laser and the positions of the optomechanical elements (Fig. 6). The same PC is used to collect the diode data. Via an I/O card the PC will have access to the spill signal.

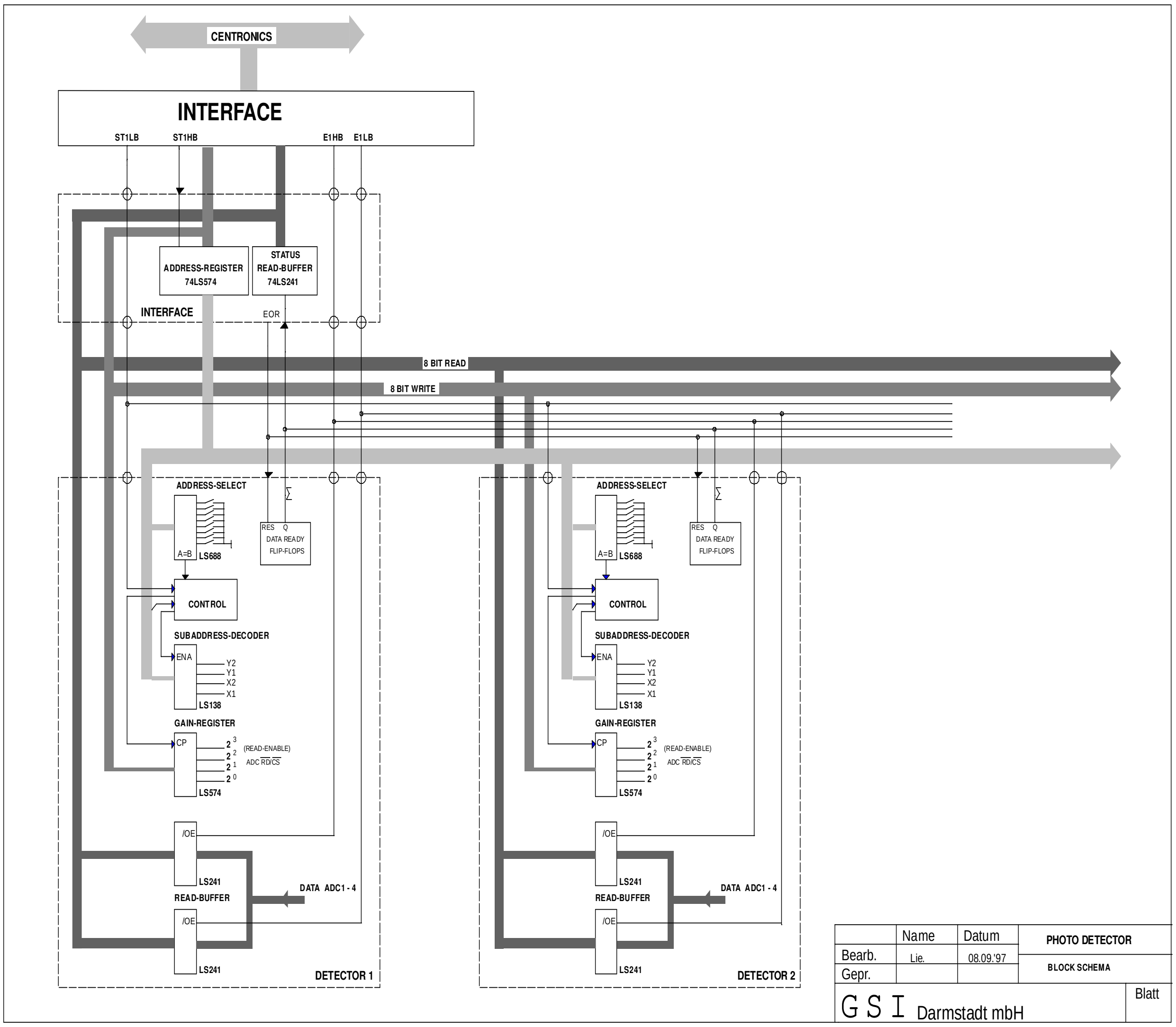

Fig. 5. Digital part of the diode readout electronics.

In addition, during the laboratory tests the PC is used to read out the beam profile data obtained from a camera, and to control two Ealing linear translation stages used to calibrate the diodes. These two applications run only under WIN95.

During experiments the PC will be located in the cave. It will run under Linux and it will be accessible via Ethernet.

The software to control the laser and the Picomotor Driver under Linux had to be written. The low level communication routines were written in C, and the user interfaces are in TCL/Tk. Since TCL/Tk provides a mechanism for communication between applications, it should be easy to implement procedures with information exchange between different devices, for example to generate the laser pulses at defined times in respect to the beginning of spill.

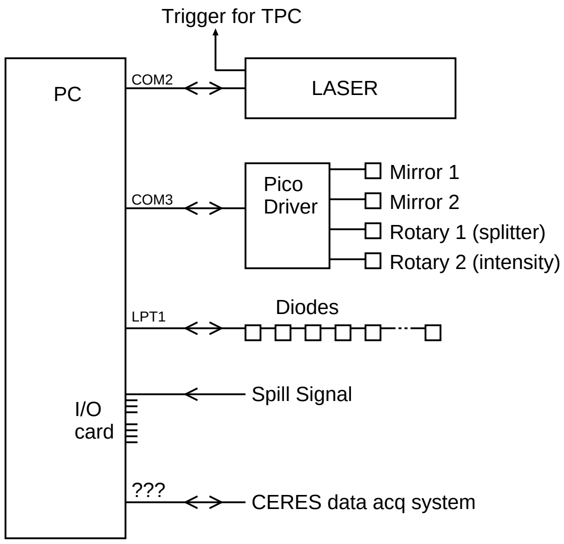

Fig. 6. Communication scheme.

4 Schedule

I would like to have the diodes, the mirror holders and the splitter ready and calibrated in the middle of February. Then we could go to CERN in the second half of February, install the mirrors and the splitter, setup the laser, shot on mirrors and measure positions of the rays outcoming from the plate in the TPC side. The TPC side of the plate will not be accessible later after the field cage is installed.

For the end-of-April run we will have a complete system with mirrors on beam axis. For the summer runs we will provide mechanism for removing the mirrors during spills.

5 What we need

1. Holes in field cage, windows glued to it. The windows will be available by middle of February.
2. Backplate without TPC available for us for second half of February to do the following:
   (a) Mount mirror holders
   (b) Mount rotating mirror splitter
   (c) Set laser in a position such that the beam can reach splitter
   (d) Generate laser pulses and measure the positions of the beams coming out of the backplate
   (e) Glue the windows to the backplate
3. Infrastructure in cave, Jura side, and in the place where TPC will be assembled and tested:
   (a) Support for laser (a very stable table) 2.5 m per 0.5 m, and a place to put the power supply (80 cm high electronics rack). Maximum distance between laser and power supply is 7 meters.
   (b) Cooling water connection (3 l/minute at 2 bar and 20 degrees)
   (c) Electric power connection
   (d) Ethernet connection
   (e) Whatever is needed for safety
4. Spill signal
5. Possibility to feed the diode data (80 12-bit integers + something like a time stamp or event number) into the DAQ stream

References

[1] Polytec, Polytec-Platz 1-7, D-76337 Waldbronn, Germany, Tel 07243-6040, Fax 07243-69944.

[2] Spectron Laser Systems, 8 Consul Road, Rugby, Warwickshire CV21 1PB, England, Tel 01788-544694, Fax 01788-575379

[3] New Focus, Inc., 2630 Walsh Avenue, Santa Clara, CA, U.S.A., Tel 408-980-8088, Fax 408-980-8883.

[4] GIGAHERTZ-OPTIK GmbH, Fischerstr. 4, D-82178 Puchheim, Tel 089-8901590, Fax 089-89015950.