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September 26, 2003

ECAL Monitoring Light Source at H4[1)]

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Abstract

This note describes the design of laser based monitoring light source for lead tungstate crystal electromagnetic calorimeter and its installation at the H4 test beam site at CERN. The floor layout, safety implementation and the protocol of communication with the H4 DAQ are discussed.

[1)] Work supported in part by U.S. Department of Energy Grant No. DE-FG03-92-ER40701.

1 ECAL Monitoring Light Source

The ECAL monitoring light source consists of three laser systems with diagnostics, two fiberoptic switches, a monitor and a PC based controller. Figure 1 is a schematic showing the design of the monitoring light source and high level distribution system. The determination of the monitoring wavelength and the performance of the 1st laser system can be found in reference [1]. As shown in Figure 1 each laser system consists of an Nd:YLF pump laser, its power supply and cooler unit and corresponding transformer, a Ti:Sapphire laser and its controller, and a NESLAB cooler for the LBO crystal in the Ti:S laser. Each pair of the YLF and Ti:S lasers and their corresponding optics are mounted on an optical table.

All three pump lasers are model 527DQ-S Q-switched green Nd:YLF laser, which is a commercial product by Quantronix [2]. It provides frequency doubled laser pulse at 527 nm with pulse intensity up to 20 mJ at repetition rate up to 1 kHz. All three Ti:S lasers are custom made Proteus UV(SHG) laser from Quantronix, which provides pulse intensity up to 1 mJ at repetition rate up to 100 Hz [2]. The wavelength of the Ti:S laser is tunable by choosing appropriate built-in filter. Two wavelengths are available for each Ti:S laser. As shown in Figure 1, the monitoring light source in operation consists of two laser systems, so that a total of 4 wavelengths, 440, 495, 709 and 796 nm, are available by using a 2×1 optical switch [3]. The third laser system provides 440 and 495 nm, and is a spare laser for the main monitoring laser to guarantee 100% availability of the main monitoring wavelength at 440 nm [1] even during laser maintenance. The spare laser system can also be used independently. The switching between the main monitoring laser and the spare laser is done manually.

2 Installation at H4

The requirements to chilled water and electricity for laser installation are described in reference [4]. The 1st laser system was installed at the H4 site in August, 2001 [5], and has been used in ECAL beam test since then [6]. The main experience of using the 1st laser system in beam test is that the laser environment must be adequate to allow a stable operation.

The requirement to the laser environment is summarized as follows.

1. Minimum 60 cm free space on each side of the optical table, so that fine tuning and service can be performed for the lasers and the power supply and cooler unit, which is underneath-table.
2. Room temperature stable: $22 \pm 2°$C. Dust free and humidity control: $< 60\%$.

Following these requirements, Figure 2 shows the design of the laser barracks constructed at H4. The total area of this laser barracks is about 45 m^2, including three laser cells and a control cell hosting optics and electronics mounted on three racks. Each laser cell is measured as 3×3 m^2 and has its own door, so that all laser systems are safeguarded by double door. The entire laser barracks is air-conditioned to maintain adequate operation temperature and stability. The $3' \times 5' \times 2''$ optical table with weight of about 300 kg provides effective vibration isolation. The Nd:YLF power supply and cooler unit weights 160 kg. The total weight for each laser system is about 460 kg. The floor layout of the laser barracks is also shown in Figure 2.

Chilled water from 7 to 18°C is supplied in each laser cell through a filter. A regulator regulates chilled water pressure from 1 to 7 kg/cm^2 measured by a pressure gauge. The flux of chilled water is required to be 16 to 24 l/min measured by a flow meter. Each YLF laser power and cooler unit consumes about 10 kW, provided by a three Phase, 400 V, 50 Hz and 30 A/Phase electrical power supply through a transformer. While most heat generated by the laser power and cooler unit is removed by the chilled water, about 1 kW heat dissipates in the laser cell. The Neslab cooler for the Ti:S laser requires electrical power of single phase, 220 V, 50 Hz and 10 A, with a power consumption about 1.65 kW. Total heat load in each laser cell thus is about 2.5 kW. Figure 3 shows the equipment installed on three racks in the control cell, including PC, readout electronics, laser diagnostics, optical switch and digital scope. The sum of heat dissipation of all these equipment is also about 2.5 kW [4]. As shown in Figure 2, four wall mounted air-conditioning units are used to remove the heat generated in the laser barracks. The control cell also equipped with 10/100 base T Ethernet connection for PC to communicate with the H4 DAQ computer.

3 Laser Safety

Figure 4 shows the design of rigorous safety measures implemented for the laser system. An “Emergency Stop” button turns off all lasers when it is pushed. All lasers are protected by double door with interlocks. Warning labels and flashing lamps are installed outside the laser barracks. Inside the laser barracks, red and flashing warning lamps are installed for each laser, indicating laser power on and laser shutter open respectively. The power switches of these lamps also provide interlock so that the red and flashing lamps must be on to turn on the laser power and shutter respectively, as shown in Figure 5.

The design of the interlock system is as follows. An overall interlock closes all laser shutters if the optical fibers used to transport laser pulses were accidentally broken ("Level 2 TTL Input" in Figure 4) or the cover of the calorimeter module, which receives laser pulse, were open ("Calorimeter" in Figure 4). The "Level 2 TTL Input" is a TTL signal at high level if the level 2 fanouts receive laser pulse. It goes to low level if the laser pulse does not reach level 2 fanouts because of, e.g., accidentally broken fiber. In addition, individual interlock closes a laser shutter when the cover of the laser or the inner door of the corresponding laser cell were accidentally opened. This interlock may be bypassed during laser maintenance by a manual switch, which enables the interlock on the outer door of the barracks. This design guarantees that the laser light is not visible outside the laser barracks during laser maintenance even when an inner door and corresponding laser cover are both open.

4 Communication with the H4 DAQ

The laser system operation is controlled by a PC, which sets laser run parameters and collects laser performance data measured by diagnostics [1]. During beam test, the laser control PC will function in a slave mode. The communication of the PC with the H4 DAQ is carried out through Ethernet. At the beginning of each run, the H4 DAQ sets and checks laser parameters by sending a command file, and the laser responds to the H4 DAQ by sending an acknowledge file. The following laser operation parameters are controlled by the H4 DAQ: laser wavelength, its internal linear attenuator and the output channel number of the 1×80 optical switch.

When the H4 DAQ is satisfied with the laser setting, it sends a NIM trigger signal to the laser and the later acknowledges by sending a NIM timing signal to the H4 DAQ, as shown in Figure 1, indicating a laser pulse of defined wavelength is sent to the designated switch channel. The delay between the DAQ trigger and the laser pulse is about 5 μs and can be adjusted. This light source can accommodate trigger rate up to 100 Hz. The wavelength change, however, takes about a minute. Depending on the distance, the channel change may also take up to a minute. Additional information concerning laser performance is also available for the H4 DAQ. They are YLF and Ti:S pulse shape spectra, and the average and r.m.s. of the energy, full width at half maximum (FWHM) and center timing of the monitoring laser pulse. The protocol of the communications between the laser and the H4 DAQ is defined as follows.

1. The command file from the H4 DAQ to the laser:

COMMAND TYPE (int)	0: request laser parameters
	1: set laser parameters
	2: get laser parameters and pulse information
WAVELENGTH (int)	0: 440 nm
	1: 495 nm
	2: 709 nm
	3: 796 nm
ATTENUATOR (int)	1 – 99 % of laser power, in 1% step
SWITCH CHANNEL (int)	1 – 80
CHECK-SUM (int)	Bitwise inversion of the sum of preceding 4 data

2. The acknowledge file from the laser to the DAQ:

COMMAND TYPE (int)	0: setting in progress
	1: setting finished, the laser parameters are ready
WAVELENGTH (int)	0: 440 nm
	1: 495 nm
	2: 709 nm
	3: 796 nm
ATTENUATOR (int)	1 – 99 % of laser power, in 1% step
SWITCH CHANNEL (int)	1 – 80
CHECK-SUM (int)	Bitwise inversion of the sum of preceding 4 data

or

COMMAND TYPE (int)	2: laser parameters and pulse information are ready
WAVELENGTH (int)	0: 440 nm
	1: 495 nm
	2: 709 nm
	3: 796 nm
ENERGY (int)	1 - 99 % of laser power, in 1% step
SWITCH CHANNEL (int)	1 - 80
EVENT (Iint)	Number of laser pulses being averaged
ENERGY (int)	Average of pulse energy [au] x 10,000
R.M.S.$_{energy}$ (int)	r.m.s. of pulse energy [au] x 10,000
FWHM (int)	Average of pulse FWHM [ns] x 10,000
R.M.S.$_{FWHM}$ (int)	r.m.s. of pulse FWHM [ns] x 10,000
CENTER (int)	Average of pulse center timing [ns] x 10,000
R.M.S.$_{center}$ (int)	r.m.s. of pulse center timing [ns] x 10,000
WC$_{ylf}$ (int)	Word counter for YLF pulse shape
WC$_{tis}$ (int)	Word counter for Ti:S pulse shape
DATA[WC$_{ylf}$+WC$_{tis}$] (int)	Array of pulse shape data
CHECK-SUM (int)	Bit wise inversion of the sum of preceding (13 + WC$_{ylf}$ + WC$_{tis}$) data

Note that the average and r.m.s. data are calculated by the laser control PC with pulse samples taken by digital scopes, and will be reset to zero after sending pulse information to the H4 DAQ.

Acknowledgments

Many useful discussions with Drs. J. Bourotte, M. Haguenauer, R. Magnier, R. Pintus and J. Rander are acknowledged.

References

[1] L.Y. Zhang, K.J. Zhu, R.Y. Zhu and D. Liu, *Monitoring Light Source for CMS Lead Tungstate Crystal Calorimeter at LHC*, *IEEE Trans. Nucl. Sci.* **NS-48** (2001) 372.

[2] L.Y. Zhang and R.Y. Zhu, *Monitoring Lasers for PbWO$_4$ ECAL*, **CMS IN 1999/014**.

[3] L.Y. Zhang and R.Y. Zhu, *Evaluation of a DiCon GP-700 1 $\times$ 2 Optical Switch*, **CMS IN 1998/031**.

[4] L.Y. Zhang, K.J. Zhu and R.Y. Zhu, *Installation of ECAL Monitoring Light Source*, **CMS IN 2001/008**.

[5] http://www.hep.caltech.edu/~zhu/ryz_mon_010904.pdf.

[6] http://www.hep.caltech.edu/~zhu/ryz_mon_021015.pdf.

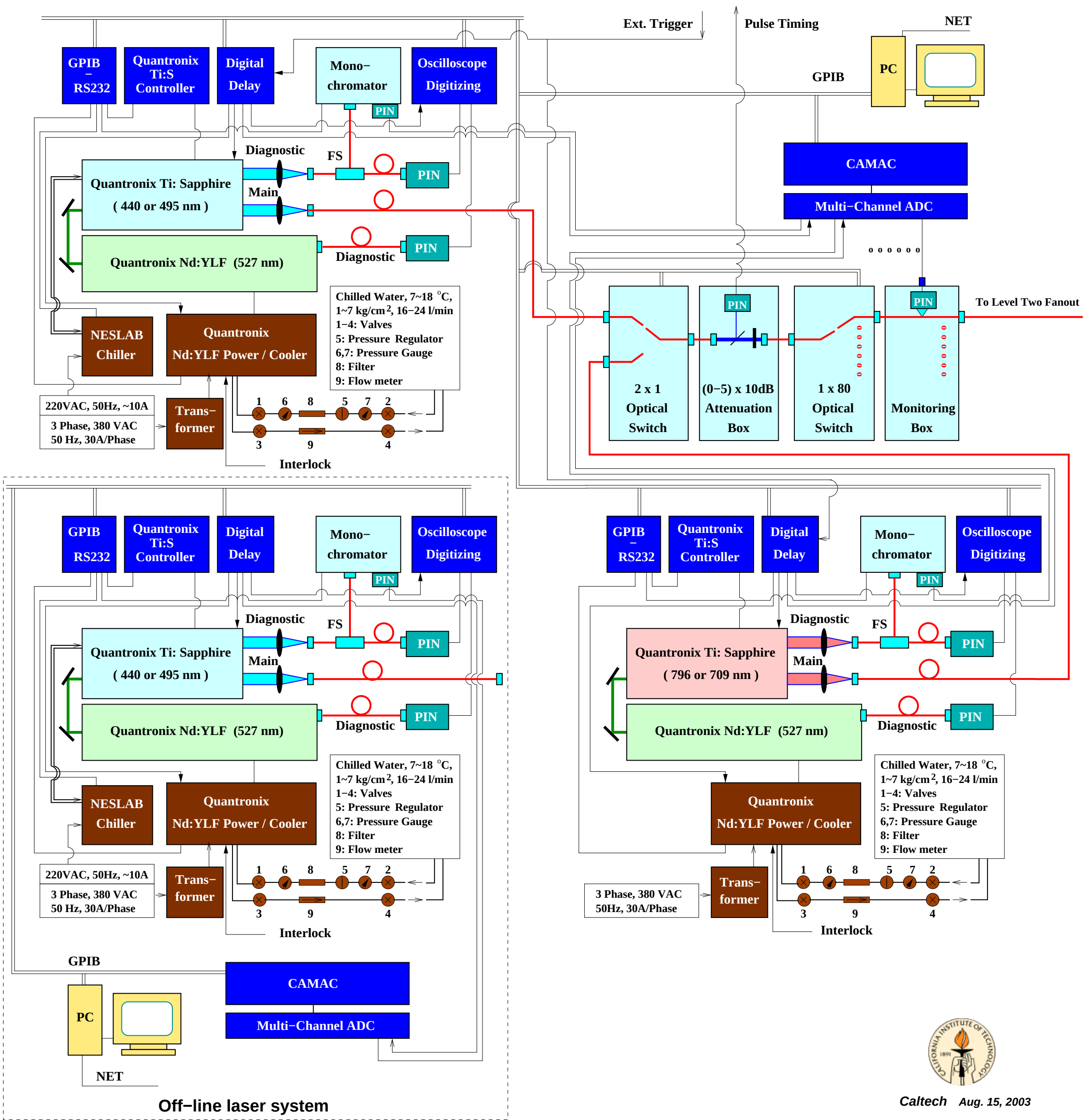

Figure 1: Monitoring light source and high level distribution system.

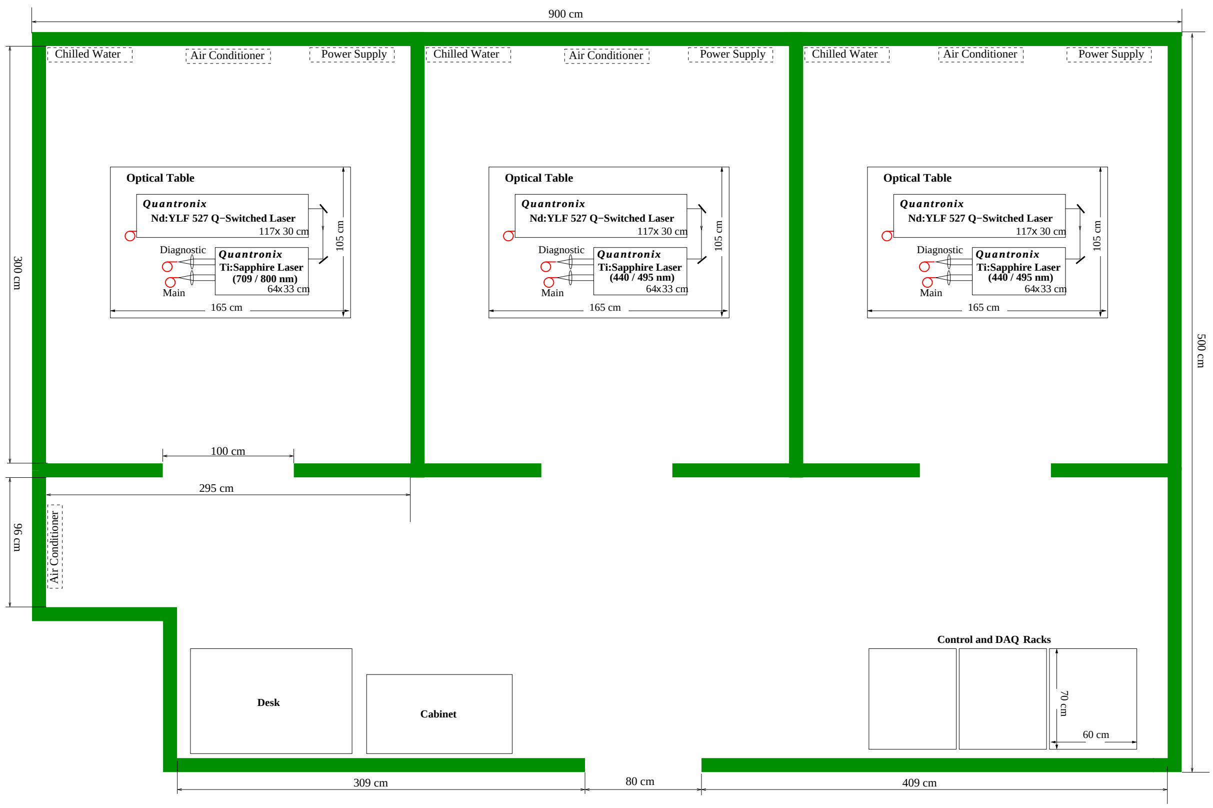

Figure 2: Laser barracks design at H4.

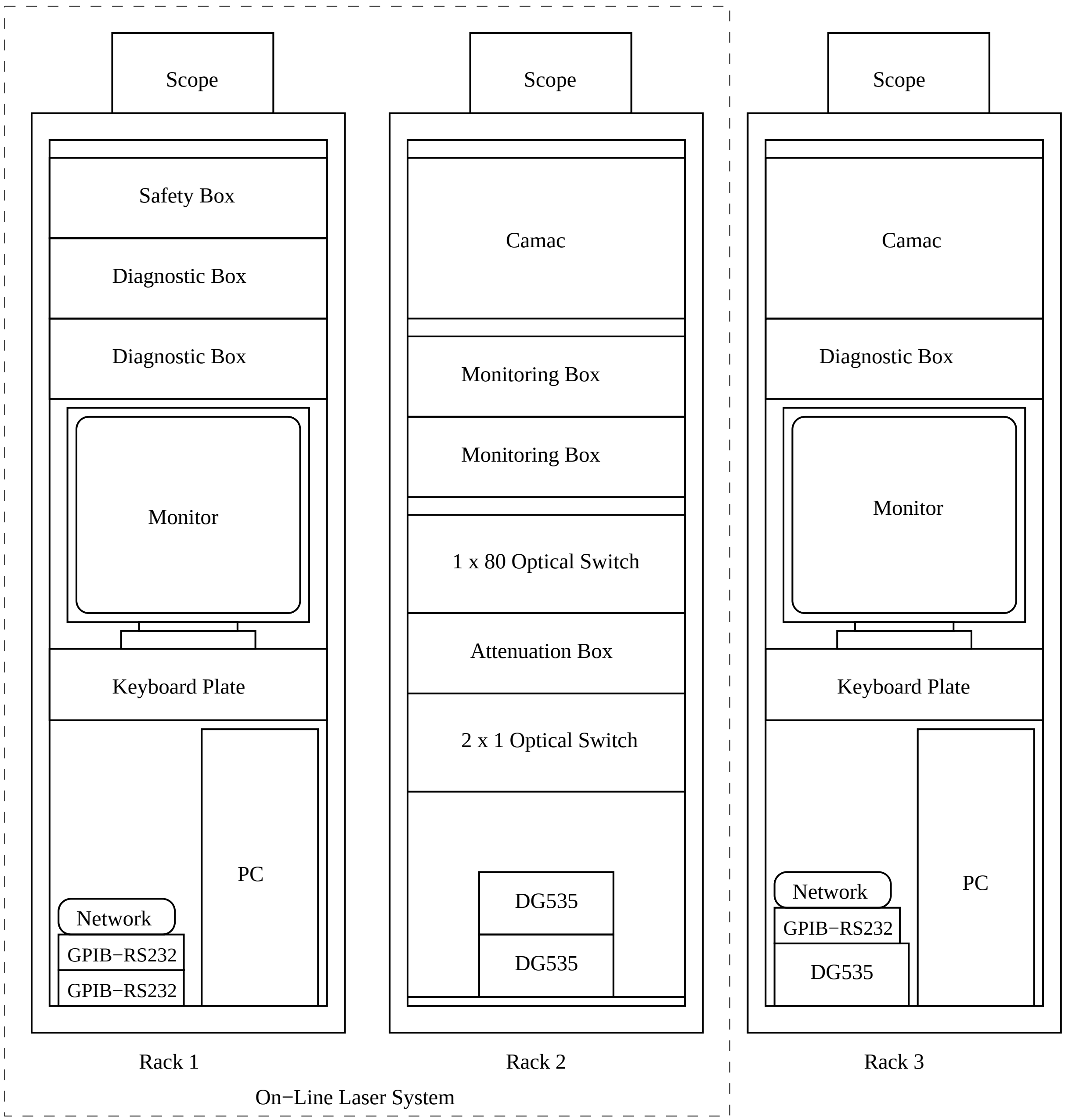

Figure 3: Arrangement of equipment in three racks.

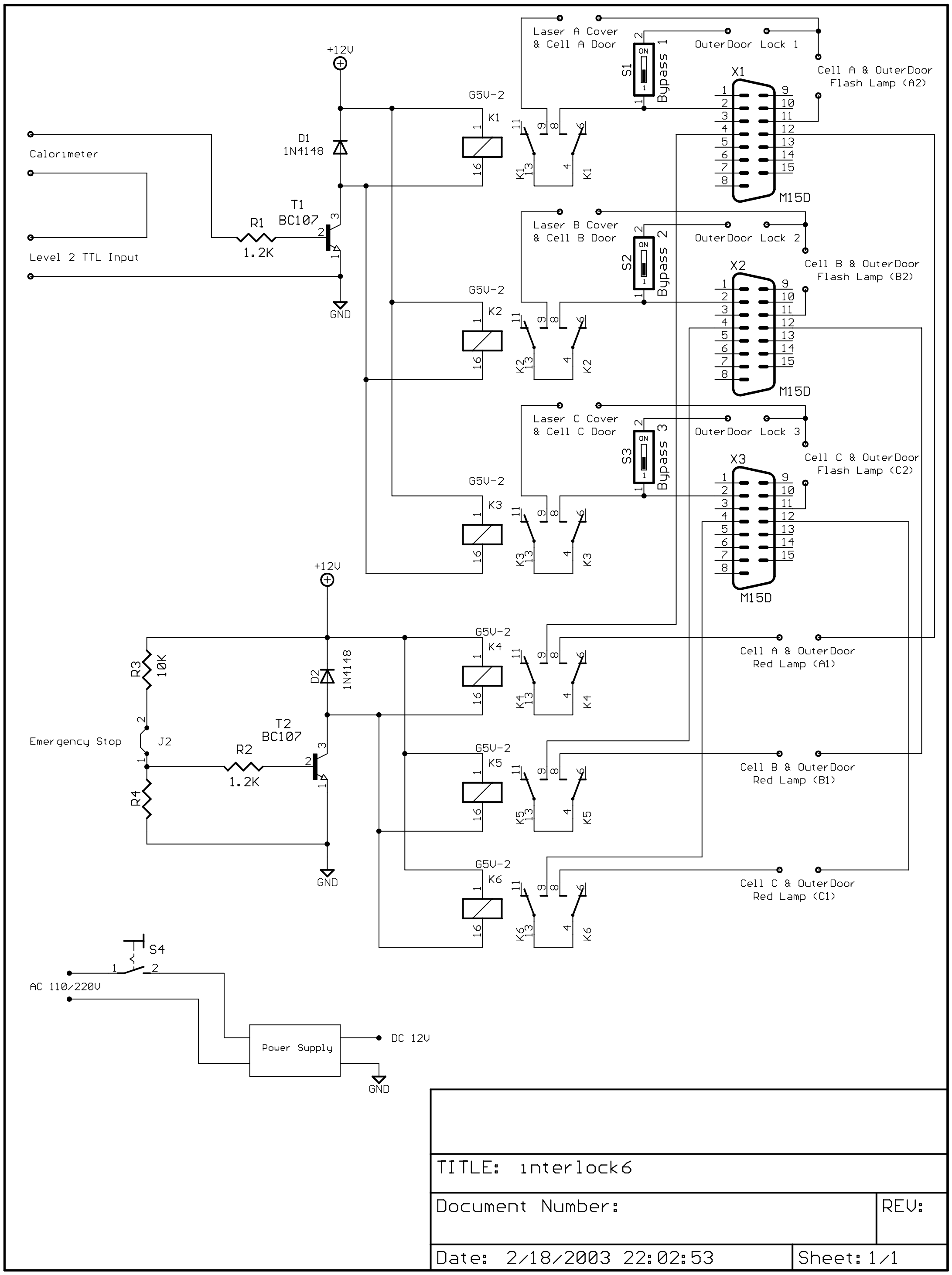

Figure 4: Implementation of the laser safety.

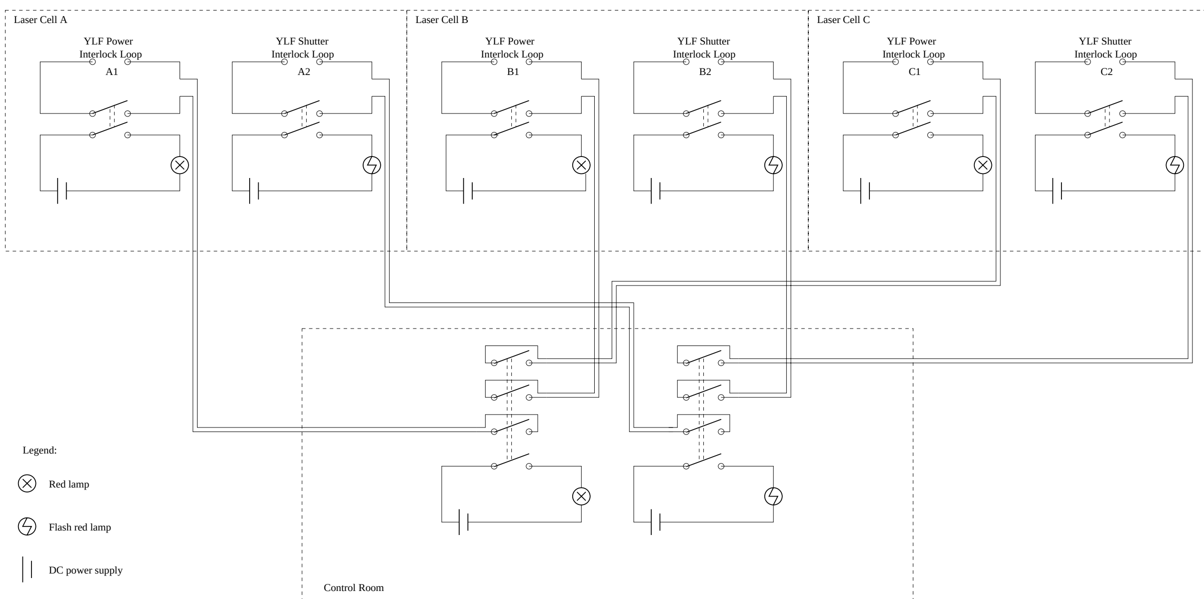

Figure 5: Red and flashing lamp switches for each laser system.