Astra Gemini control system

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Introduction

The original Astra control system was built to enable target area users to request shots and triggers, change energy modes and levels, control shutters, etc. It runs alongside the timing hardware which keeps the pump lasers, Pockels cells etc. firing at the correct time.

The Gemini project required the expansion of the existing control system to enable Astra to service both Gemini and TA2 target areas simultaneously. This gave rise to a multitude of logical problems since both areas could require full power simultaneously, the pulse stretch and Dazzler patterns are different for each area and Gemini will be firing full power shots on a strict 20 second cycle.

Hardware

The existing system was DOS based written in Turbo Pascal 6, on a 486 PC and had been used reliably for 7 years. However this combination of hardware meant that the existing control cards were almost obsolete and newer models were not compatible with either the software or hardware. To future proof the system it was rebuilt from scratch and rewritten in Visual Basic for Windows. This also had the advantage of allowing the system to be built off line and minimise the disruption caused to TA2 during its installation.

To give the necessary number of digital I/O channels a rack mountable PC with 12 PCI slots was purchased. Five of these slots were filled with 72 way I/O cards to read and control all the Gemini data channels. Breakout boxes to enable each component to be connected to the control PC were manufactured by the electrical group. Communications, where possible, were made using Ethernet to send and receive data from other PC's and devices on the network, see Figure 1. Some of the hardware developments are listed below:-

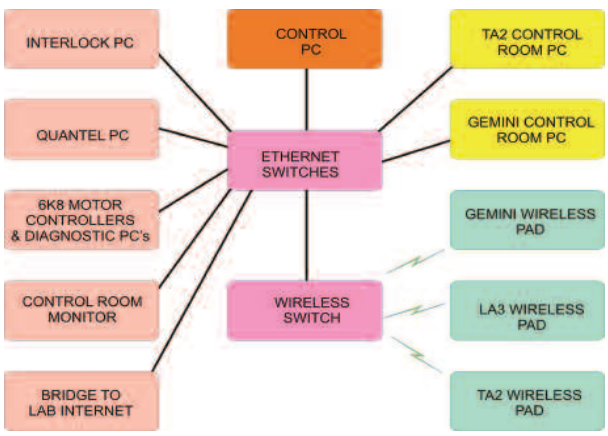

Figure 1. Map of Ethernet hardware on the Gemini control network. The control PC is a key part of the Gemini Control System, interacting with nearly all the network hardware.

Dazzler Pattern Selection

The original Astra Dazzler was delivered with the standard 2 memory configuration. Additional memory was purchased so that different patterns could be sent to all three target areas. A complex set of triggers was required by the Dazzler controller to select each pattern. Circuitry was also built to create these additional triggers so the pattern can be selected on demand by the control software.

Double Stretching

To amplify pulses to their full energy without unwanted non-linear effects the optical system was redesigned to "double stretch" the Gemini pulses to ~1ns by building the stretcher into an optical cavity and switching the pulses out after two passes with a Pockels cell. Pulses for TA2 would only be single stretched, i.e. switched out after a single pass. Thus to change between Gemini and TA2 pulses it is necessary for the control system to retime the switching Pockels cell and subsequent amplifiers in a tenth of a second. To compensate for the additional losses of the second pass in the stretcher it is also necessary to automatically increase the pump power to increase the amplification in the first amplifier for these pulses. A computer controlled selection circuit using GHz bandwidth relays was built in house to switch different timing signals through to the Pockels cell and amplifiers. The switching was synchronised to the 10Hz to avoid tripping the pump laser due to missing charge triggers.

Waveplates

The original Astra system had prototyped a large aperture (>60mm dia) rotational mount based on a large ID bearing driven by stepper motor giving approximately 200 steps over the 45° motion of the waveplate. An angular encoder returned the absolute position of stepper motor (care was taken that the motor could not turn more than 1 revolution). The design was standardised by using the 6K8 motor controllers employed elsewhere in the department to drive the mounts. The control software has been demonstrated to move the waveplate to any position within 2 seconds.

Fast shutters

To deliver just one shot to target it is vital to have a shutter which can open within 100 ms. For the Gemini system this must allow a 40mm diameter beam to pass. This movement proved beyond the capabilities of the fast galvo used in the original Astra system. A new shutter was developed using a bistable solenoid rotary actuator, Figure 2. This device rotates through 90° and has a stable position at either end of its motion. Thus it is only energised when it is actually moving and reduces the potential heat sources on the optical bench. Tests showed that it is capable of opening or closing within 40 ms. However, it did generate significant vibrations when the blade stopped and it was

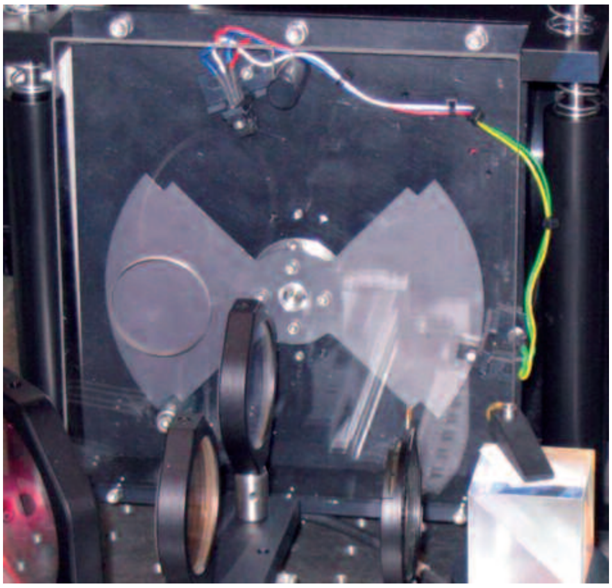

Figure 2. Fast shutter in position, it is capable of opening or shutting in less than 100 ms.

necessary to isolate it mechanically from the table. Circuitry was also constructed to synchronise the motion with the 10Hz of the laser.

Beam switching and Operating Modes

A schematic of the beam switching layout is shown below, Figure 3. The primary energy split into two beams is done by a movable half-wave plate and a polarising beamsplitter cube. Each beam line then has a fast mechanical shutter, capable of selecting a single pulse at 10 Hz as described above. Following the shutter is a sequence of attenuating components exactly as in the current TA2 beam line: a waveplate/polariser combination for continuous energy control, a slide-in 98% reflecting mirror with an AR-coated compensating plate, and a 95% reflecting mirror.

As far as the primary waveplate is concerned, the operational modes in the target areas are Low Power (LP), Medium Power (MP), High Power (HP) and Full Power (FP) (Gemini only). There are also 'no activity' modes where nothing is happening in one area, so the laser can be set up for the other area alone. For TA3, HP and FP are equivalent, as the only difference is whether the Gemini pump lasers are fired or not. The table shows the default settings of the primary waveplate for each of the combinations. The first figure is the percentage sent to TA2 and the second the percentage sent to LA3/TA3. Whether the pulse is singly or double stretched is primarily determined by which area is taking high power shots.

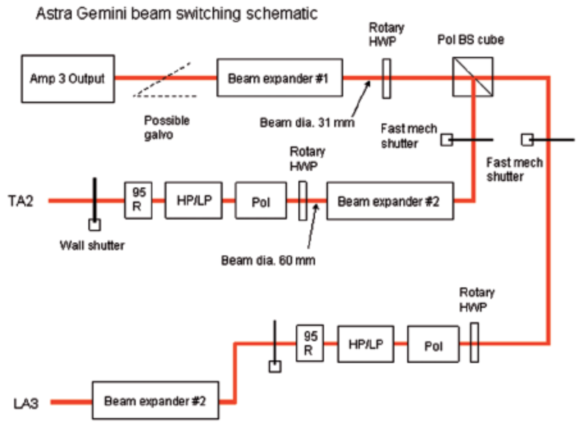

Figure 3. Beam switching layout.

The control system was programmed so that if a High or Full power shot is requested while the other target area are aligning with the waveplate in the 50/50 zone, then the waveplate momentarily moves to the 100% position, the shot is fired and the plate returns to its mid position.

The fine energy control is done by also controlling the two waveplates in the separate beams after the split. The high and low power slides were embedded in the interlock system and further software written to read back their status.

There are two sources of conflict that may arise during simultaneous operation of TA2 and TA3.

1. TA2 shot sequences.
When TA2 fire shot sequences at e.g. 1 Hz, they in effect take control of the beam. The switching cannot operate fast enough to send intermediate 10Hz pulses to LA3/TA3 (if they are doing alignment). If TA3 request a shot, they will interrupt the TA2 sequence, which may or may not cause problems.

2. Both areas using 10Hz.
When both areas are doing alignment or setup using 10Hz pulses, which pulse duration should be selected? The pulses can either be singly-stretched or doubly-stretched, but if they are going to both areas, one pulse will always finish up at 530 ps.

Currently these issues have not been resolved, but software is written in such a way that the priorities can fairly easily be changed.

Full power Gemini shots

To maintain the beam quality from the Quantel pump lasers it is necessary to fire them every 20 seconds to keep the amplifiers at a constant temperature. When a full power shot is requested it must be synchronised with the next Quantel shot on this 20 second cycle.

Table showing default position of primary waveplate dependent on energy mode in each target area

TA2→ TA3↓	No activity	Low/Medium power	High power
No activity	Don't care	50/50	100/0
Low/Medium	50/50	50/50	50/50
High power	0/100	50/50	100/0
Full power	0/100	50/50	100/0

Theoretically it is possible to fire alternate amplifiers every 10 seconds, but it was decided not to implement this mode of operation.

Software

To accommodate these complex control and timing issues it was decided to use a large array showing which devices would be controlled over the next two minutes. (Two minutes was chosen as it was originally planned to fire the Quantels once every minute). The firing times of the Quantels are entered into this array allowing the other shots to be planned around them.

The software was written in Visual Basic on a Windows Platform. This was chosen due to the experience in the group and because there are no timing critical situations which would be compromised by the Windows environment. All the nanosecond timing actions are carried out by the external Stanford and Bergmann delay generators, all that is required is that the software completes one control cycle within the 10Hz operation of the laser. The digital outputs only need be accurate to 10's of milliseconds within the 100ms cycle. The software is written in a non-object orientated fashion, i.e. the main loop never exits, the timers were found to be very unreliable and unusable for 10Hz timing.

Wireless pad

Initially it was planned to use tethered key pads to control the laser in LA3. Due to time limitations installing the cabling the system was redesigned to use a wireless robust type PDA similar to that used in the target areas, see Figure 4. This is identical to those tested with the TA drive system and links to the main control PC via a wireless Ethernet link. The advantage of this device is that it allows a customised control panel to be designed and gives complete portability within LA3. Software for this device was written in Visual Studio (Basic).net to display the current laser status and control the shots from LA3. Communication was via UDP.

Remote monitoring

To check the shot selection logic was functioning correctly a display was created to show the control sequence arrays ("timelines") over the next two minutes. This presents the shot sequence, user triggers, Quantel triggers etc., as a set

Figure 4. Picture of wireless pad used for shot control in Astra LA3.

of time lines so that the logic can easily be visualised, Figure 5. This data is sent over the Ethernet to be displayed in the control room. Additional information on shutter and waveplate positions is also sent and displayed. It was found that displaying the same data locally in LA2 overloaded the control PC and could not be implemented.

System integration

The laser control program is one part of the larger Gemini control and diagnostics system. As part of this upgrade the existing RS232 communications were upgraded to Ethernet which involved rewriting part of the TA2 drive system program. The control PC also communicates with the Gemini control PC's to update shot numbers etc. A network diagram is shown in Figure 1. TCP communications were also written to read the status of the new Gemini interlock system and control the Quantel pump lasers.

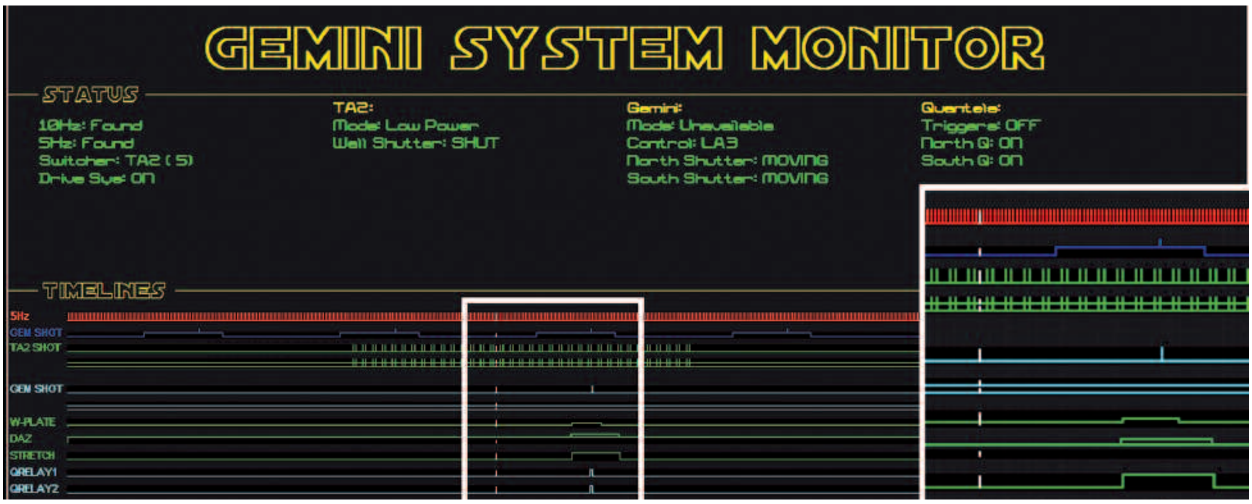

Figure 5. Gemini System monitor. Inset shows enlarged section of time lines. Blue trace shows Quantel lasers firing every 20 seconds. TA2 traces show low power double pulses into TA2 and the Quantel traces show a Gemini shot.