Low Cost Laser Beam Imaging for Daylight Tracking

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Abstract

For stations using telescopes with separated transmit/receive telescope, it is sometimes difficult to maintain correct laser beam pointing due to Coude path mirror drifts etc.; while it is usually easy to verify this correct laser beam pointing during night time, it can be more tricky during daylight.

We have installed now a small progressive scan CCD camera in the receiver package, between the first dichroic mirror (10 nm bandwidth around 532 nm) and our standard 0.35 nm daylight filter; a switched mirror can direct this green light into the SPAD (usually) OR into the CCD (to check / align the outgoing laser beam).

This progressive scan CCD is triggered by the laser start pulse; an exposure time of down to 100 µs delivers a single full frame image; feeding this into a standard frame grabber, and using software image / contrast enhancement techniques, allows us to display the backscatter of each outgoing laser beam in real time, to centre the laser beam with remote control of the last Coudé mirror, and to switch back to standard ranging within a few seconds. The system significantly improves our daylight capabilities, working nice under almost all conditions, from near-sun pointing to beginning dawn.

Procedure:

We have used since several years a standard CCD camera to detect the backscatter of the outgoing laser beam during daylight; due to the high background during daylight, it was always rather difficult to see the laser beam; as our Coudé path is not very stable – and we try to avoid more frequent adjustments than once in 6 months or so – seeing the beam (and centring it with the remotely controlled last Coudé mirror) is essential. To improve this – and to make it easier for our observers – we were looking for a significant, but cheap improvement (which excluded any solution using ICCDs etc.).

During daylight ranging, the observer now switches the mirror (fig. 1) into the path to direct the backscatter into the CCD; he centres the laser beam via the remotely controlled last Coudé mirror, and switches back the mirror. The whole procedure takes a few seconds only, but improves our daylight return rate significantly.

Hardware:

We now use a JAI M10RS progressive scan CCD; the camera has a built-in serial interface, and most functions can be set/programmed via PC; this allows easy and automatic settings and adjustments. The camera is externally triggered by the laser start pulse, starting immediately an exposure time of usually 100 µs, according to actual weather conditions, and delivers a single full frame image after each trigger.

The FlashBus MV Pro Frame Grabber handles this input, and displays the image on the PC monitor. The image obtained from this combination of CCD and Frame Grabber within our telescope was rather close to our previous equipment: It was visible only in very good conditions, and was more or less invisible in sub-optimal conditions (which was expected and calculated).

Software:

But the main advantage of this concept is the possibility of using software contrast enhancement techniques; using some demo programs (coming with the frame grabber, written in Visual C++) and implementing a very fast real-time contrast enhancement scheme, we now get remarkably clear images of the laser beam backscatter in almost all daylight conditions (haze, pointing near sun, etc.)

Our software now re-programs the internal Look-Up-Tables (LUTs) on the frame grabber; these LUTs are used anyway on any incoming image; changing these LUTs means that there is NO additional workload on the card NOR on the PC, and the whole imaging process takes almost no overhead from the PC processing time.

The incoming pixels can have brightness values between 0-255, and are usually translated 1:1 via these LUTs, leaving the original contrast of the image unchanged. We now reprogramm these LUTs, so that values from 0-120 remain unchanged; values from 121-130 are scaled to values from 0-255; values from 131-140 are scaled to values from 255-0; values from 141-150 are scaled to values from 0-255 and so on; this means that any small contrast differences of up to 10 are stretched to a maximum of 255; it also means that we can get also inverted images – or inverted part of the image - of the laser beam back scatter (fig. 2), which turned out to be of no influence at all for the clear identification of the backscatter image.

Conclusion:

The implementation was a rather low-cost, efficient way to improve significantly the visibility of laser beam backscatter during daylight ranging, our ability to correct the Coudé path offsets, and our daylight return rate due to fast, accurate centring possibility. The PC which handles this system needs very small overhead, and is free for its many other tasks.

In addition, the frame grabber can handle also various other video signal sources simultaneously, like TV, Video Camera (used for cloud detection), ISIT camera (for night time observations) etc., thus reducing the number of TV monitors etc. in our observer cabin significantly.

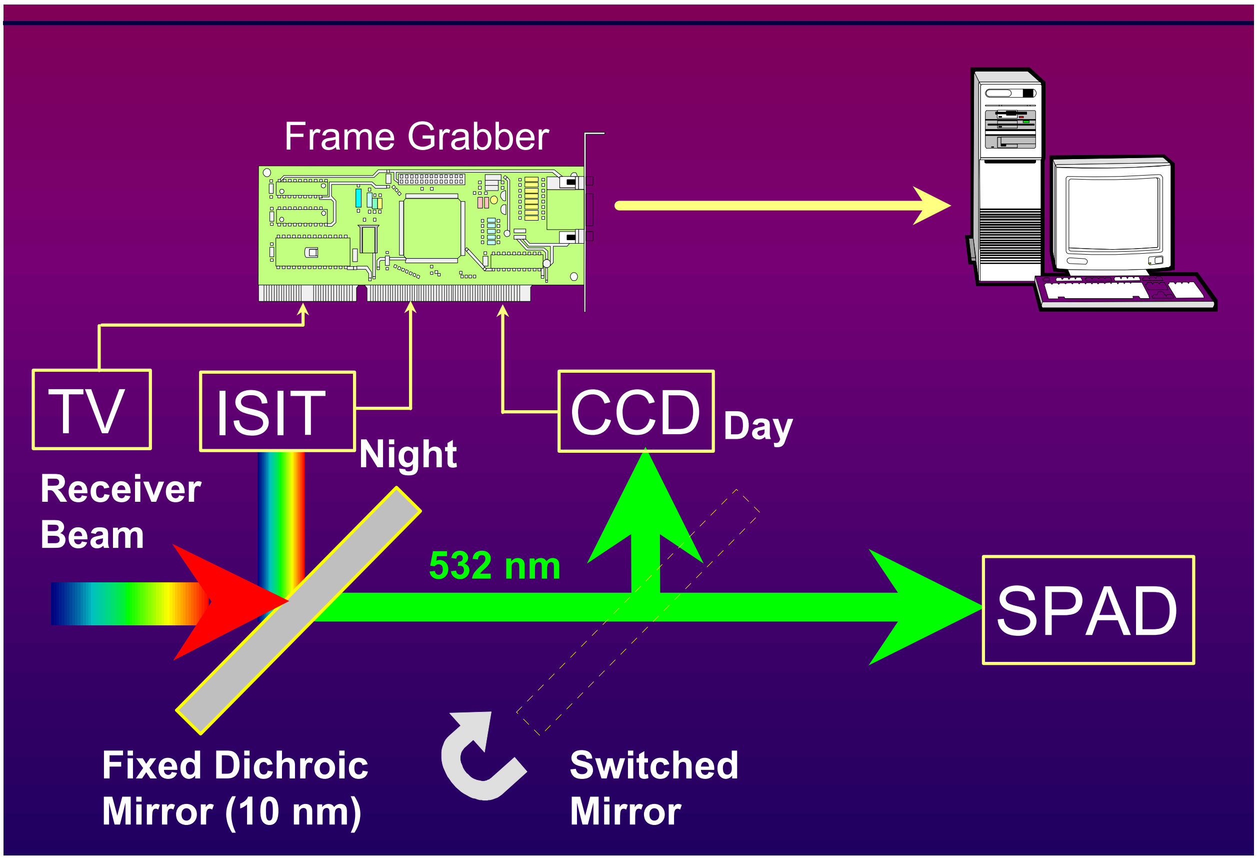

Fig. 1: Schematics of CCD-based daylight laser beam backscatter detection

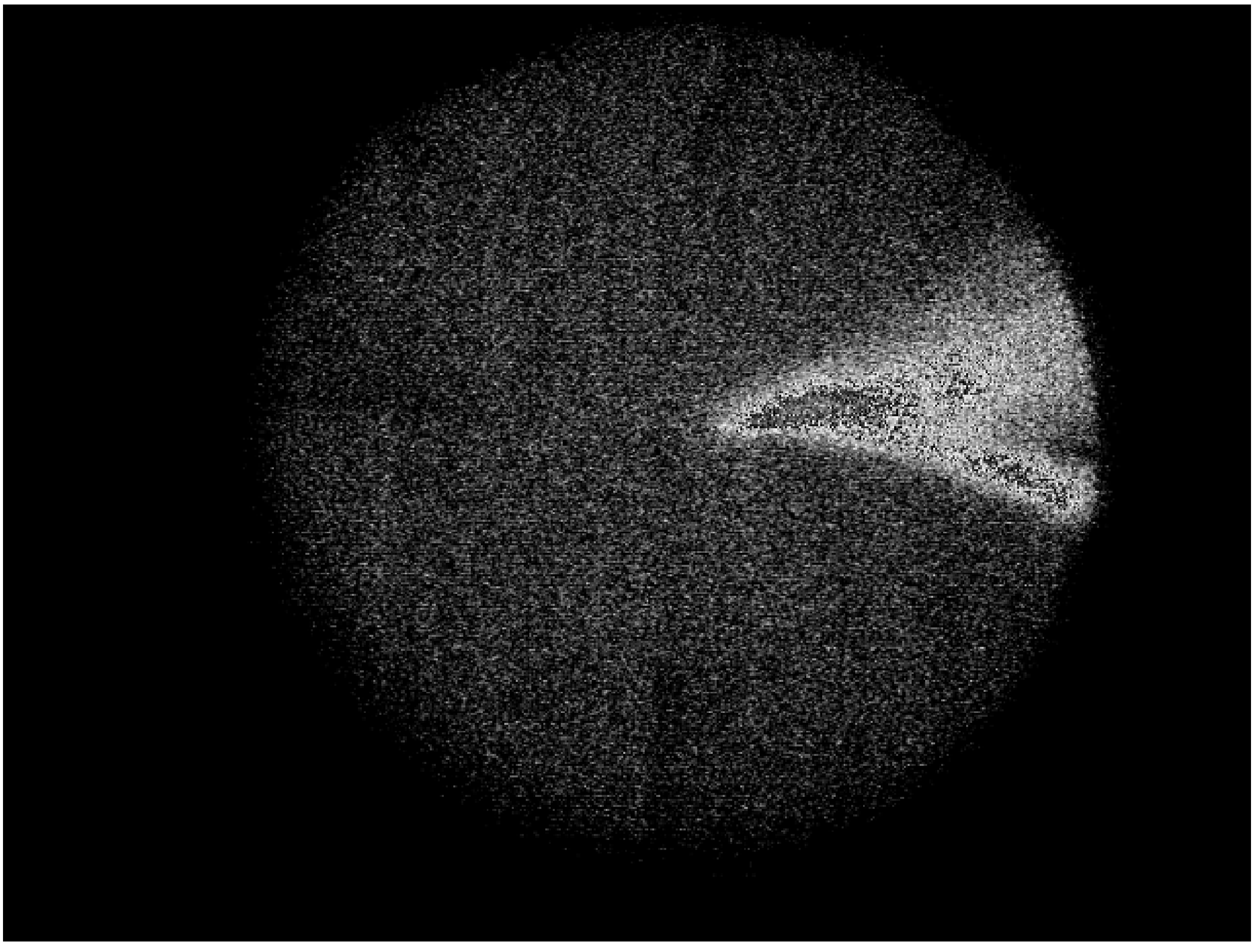

Fig. 2: Daylight Laser Beam Backscatter; Image after Software Contrast Enhancement