Two color laser ranging on ground targets

First results and projected developments

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A two color laser ranging station, devoted to research and technological developments is now able to range on ground targets.

I. Equipment used :

The main elements are :

A. Laser

Nd:YAG laser passively mode locked with 16 ps pulses at 1.06µm.
The infrared pulses are frequency doubled (0.53 µm) and are focused in an Hydrogen Raman cell (Figure 2). Out of the Raman cell we were expecting six wavelengths :

1. First order Stokes of 1.06 µm at 1.9 µm (infrared)
2. **Remaining 1.06 µm (fundamental Nd:YAG) (infrared)**
3. First order Anti-Stokes of 1.06 µm at 0.798 µm (darker red)
4. **First order Stokes of 0.53 µm at 0.683 µm (red)**
5. **Remaining 0.53 µm (doubled Nd:YAG) (green)**
6. First order Anti-Stokes of 0.53 µm at 0.436 µm (blue)

In fact we do see a great number of other frequencies.
The two color effect is measured between the 0.53 µm excitation frequency and its first order Stokes downshift at 0.683 µm.

B. Mount and optics :

A Coudé Alt/Alt mount with a pointing accuracy of a few arc seconds manipulates the emitted and received beams to aim at the targets. By now, only ground targets are aimed, but software developments will allow satellite tracking.
An aperture sharing configuration is used, with a 40 cm Cassegrain telescope. The off-axis emitted beam has a diameter of 10 cm.
For the first trials on targets, due to coating problems, the main telescope has been removed and we are working only with the Nasmyth mirror : the received beam has a diameter of 50 mm, while the emission is 10 mm.

C. Streak camera color separation and focalization.

We use an Hadland Imacon 500 SC with a double µCP light amplifier and a CCD video camera (Figure 1). Different streak speeds are available from 20 ps/mm to 5 ns/mm corresponding to 0.613 ps/pixel to 186 ps/pixel, and full screen dynamic of 350 ps to 107 ns.
The collimated return beam of 50 mm diameter is focused in the plane of a field aperture and recollimated at a diameter of 25 mm. The useful colors are separated by mean of dichroic mirrors and interferometric filters (Figures 3 & 4).
After the filters the infrared beam is focused on an APD in order to determine the light flight time.
The remaining Red and Green beams are focused through a stigmatic optical system to two thin images on the SC photocathode.
As the paths of the two wavelengths are unequal, the two color effect has to be calibrated.

II. Targets arrangement.

We installed three targets (Figures 5, 6 &7).

1. One South at around 500 m, consisting of three 10 mm corner cubes in a plane perpendicular to the direction of the range.
2. One North at 3.5 km, simple ∅ 35 mm corner cube.
3. Reflection on a quasi flat surface at 65 m South of the station.

III. Preliminary results.

Ranging on the targets is now possible with the following drawbacks :

1. The acquisition of the SC image is very slow ; each frame needs at least half a minute with a lot of non automated manipulations.
2. Maintenance of the laser is heavy with frequent dye changes and realignment. The beam is far from TEM00.
3. The photocathode of the SC is protected by a manual shutter.

We are presenting here the first results and some of the first remarks (Figures 8-13).

If we range during a session with stable meteorological parameters (computed range corrections from a model constant) the two color correction exhibits a great noise (Figures14-16).

That can be partially explained by the fact that the light's path is rather low above the ground. Hardware problems may also be part of the problem, and we are investigating this possibility. Nevertheless, we feel that in our ranging conditions the correction model extrapolated from the meteorological parameters at the station is not representing the true mean correction as well as its shot by shot variations.

IV. Scheduled improvements

A. Setup of new targets at greater distances (10 to 20 km) in order to simulate the equivalent atmospheric thickness of a satellite pass. Measure and use of the meteorological parameters at both ends of the link.

   A link between Monte Cinto (2710 m at 220 km) in Corsica and Grasse (515 m) is possible as already demonstrated more than 20 years ago. The accuracy obtained with the two color method being 3 cm shot by shot, would allow estimated relative motion around 1 cm/year to be confirmed on relatively short span time.

B. Understanding of the behavior of the Raman cell.

C. Faster acquisition and real-time processing of the SC images with a new CCD camera and a new software (the SC itself is limited to 1 kHz). An acquisition of the data limited to 50 Hz seems reasonable.

   The change of CCD will eliminate the present noise seen on the included SC images even if this problem is now drastically reduced.

D. The laser is already heavily modified in order to reach the MTBF already observed on one of our lasers (preventive maintenance less than once a year).

E. Setup and tuning of the full aperture optics.

F. Development and implementation of software for satellite tracking.

Figure 1: Streak Camera with µCP and CCD assembly.

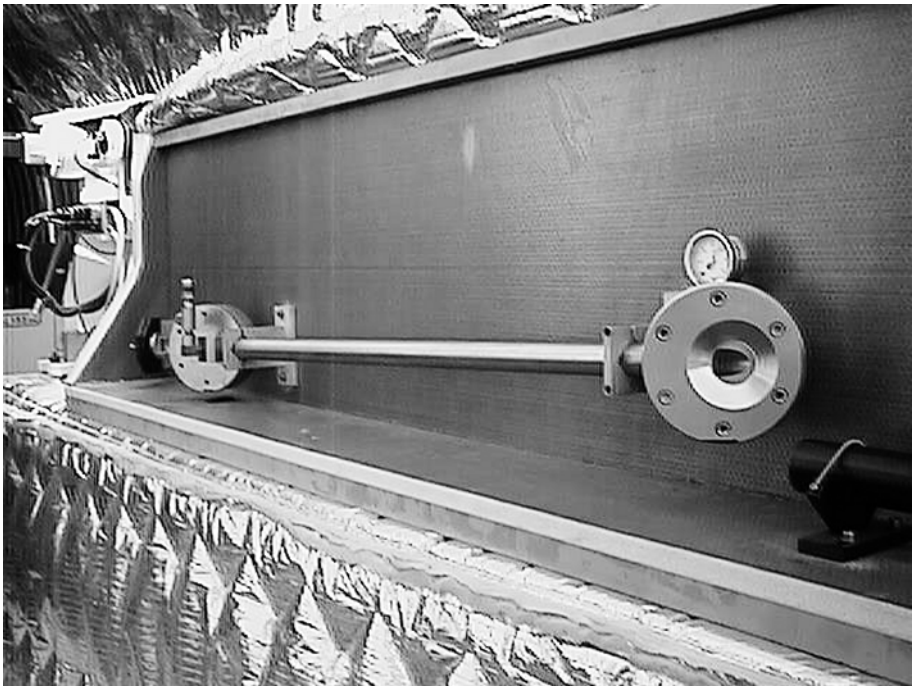


Figure 2: Hydrogen Raman cell with Brewster windows.

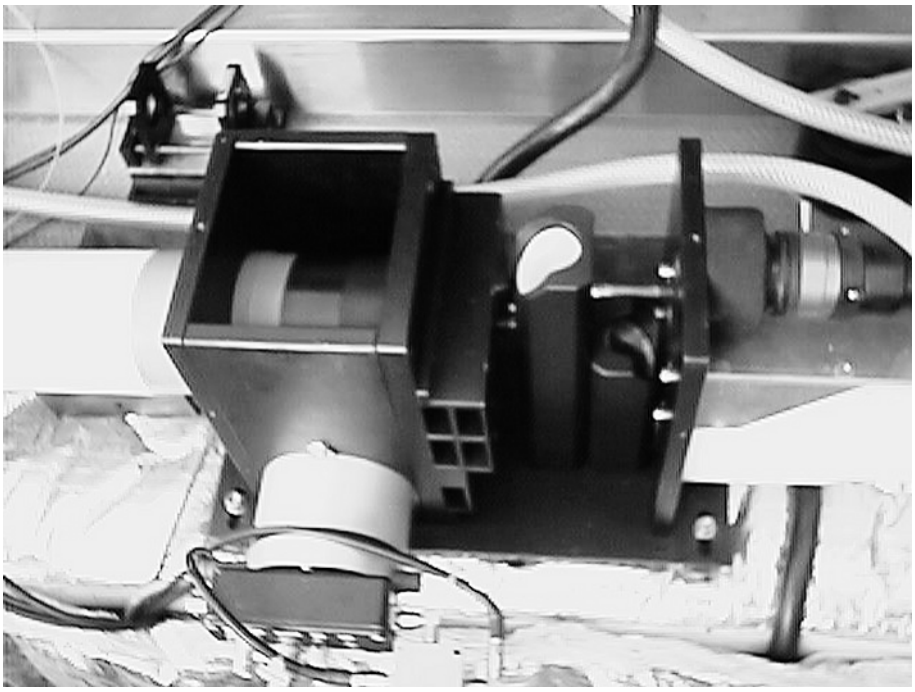


Figure 3: Color separator.

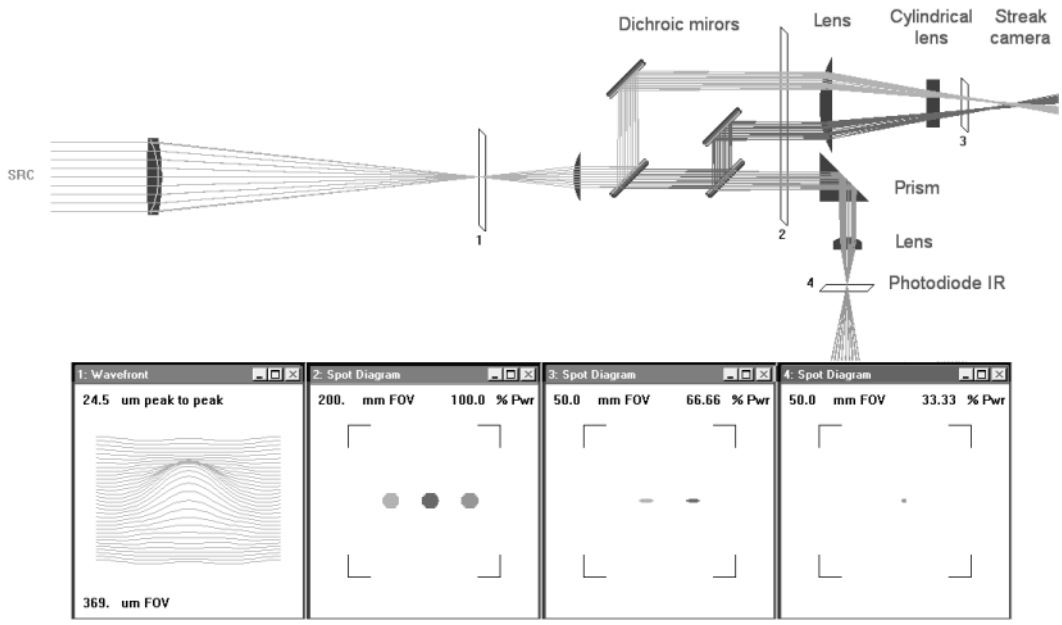


Figure 4: Optical diagram of the color separator

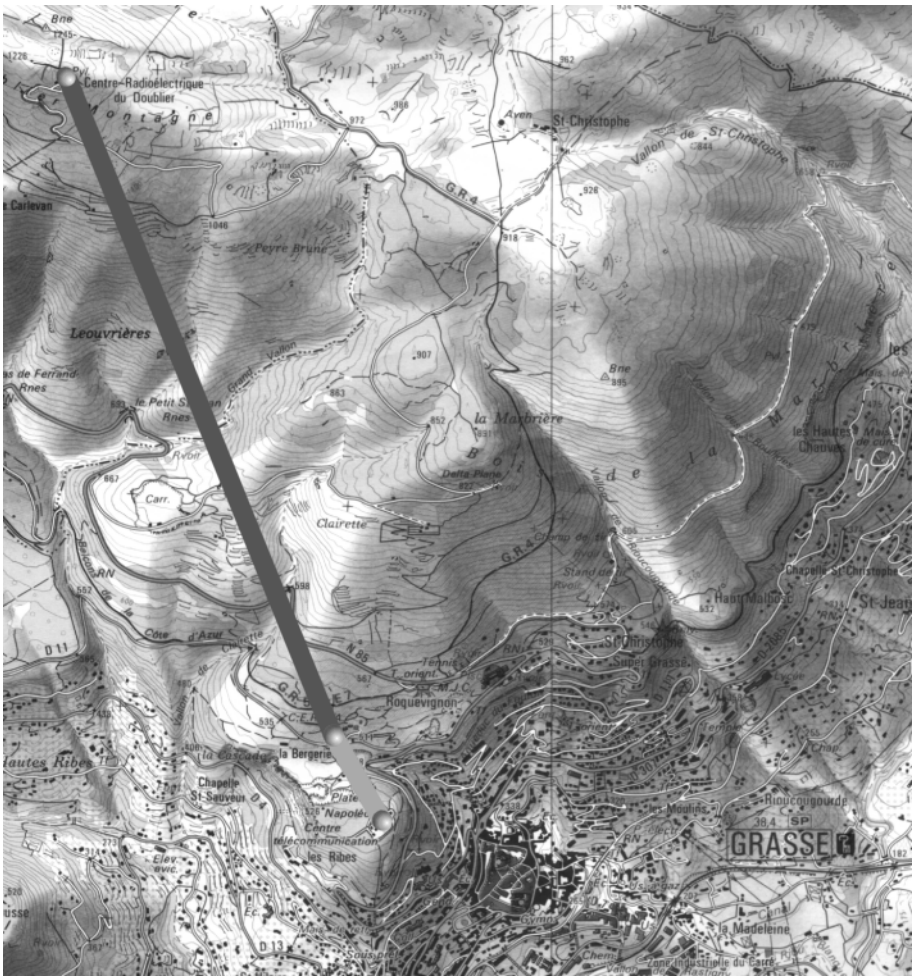


Figure 5: Map of Grasse area with station and targets situations

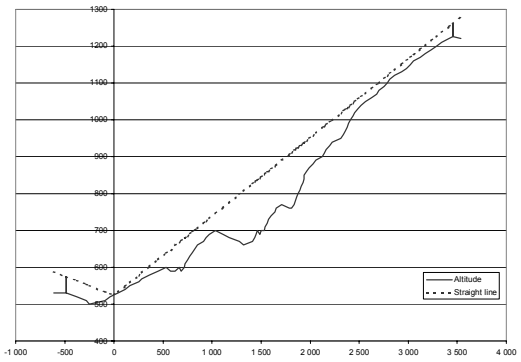


Figure 6: Profile of ground under range. The dashed line represent laser beam (straight line approximation).

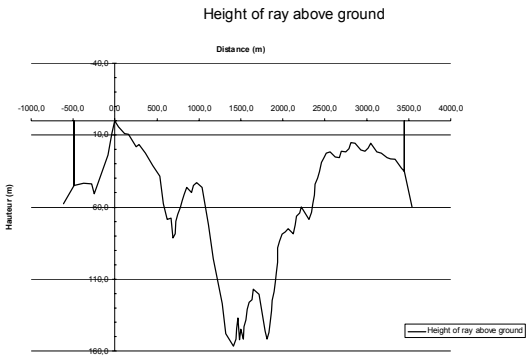


Figure 7: Altitude of the beam above ground.

Figure 8: Calibration, 29-jun-2000, picture 1
20ps/mm, 19°C, 43%, 949 hPa, 22:17
Distance: 65.5 m, Green-Red = –117.6 ps

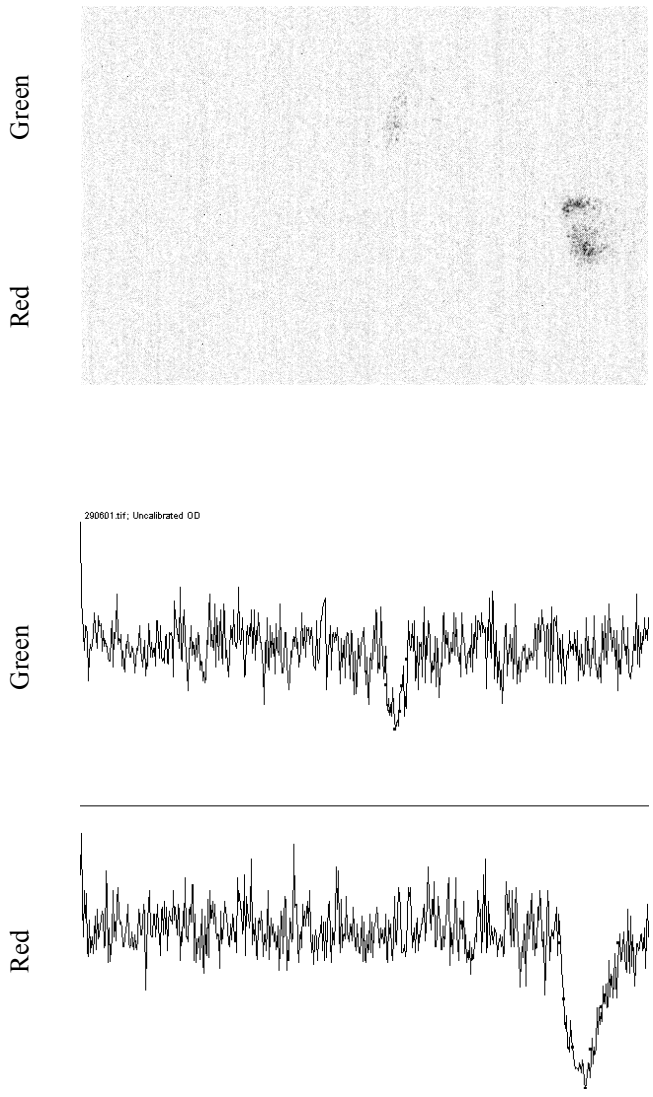


Figure 9: Calibration, 29-jun-2000, picture 3
20ps/mm, 19°C, 43%, 949 hPa, 22:17
Distance: 65.5 m, Green - Red = –113.1 ps

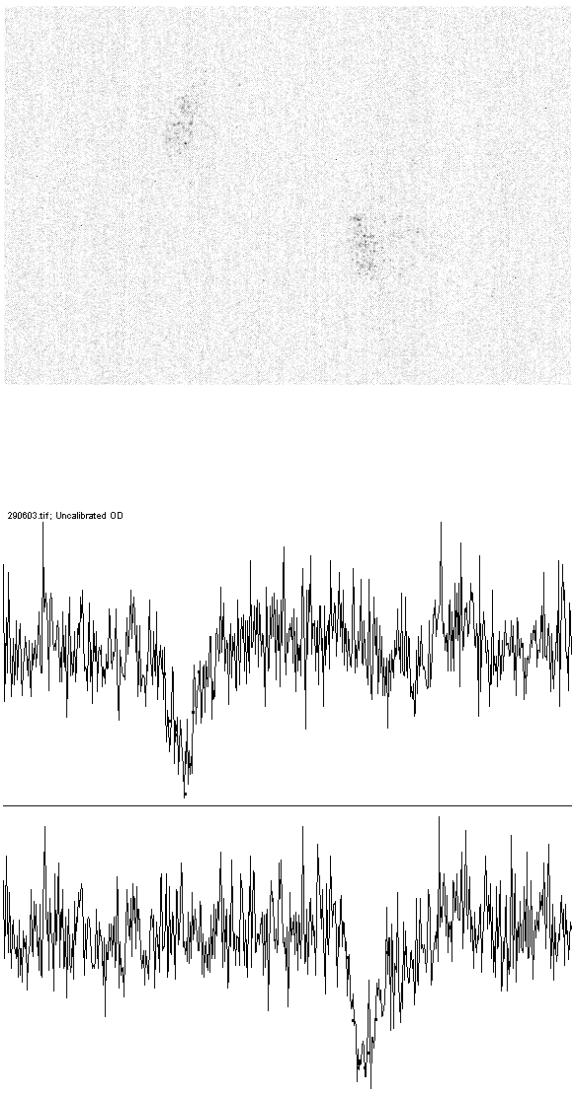


Figure 10: Roquevignon, 29-jun-2000, picture 5
20ps/mm, 19°C, 42 %, 949 hPa, 23:05
Distance: 494.5 m, Green-Red = –97.8 ps

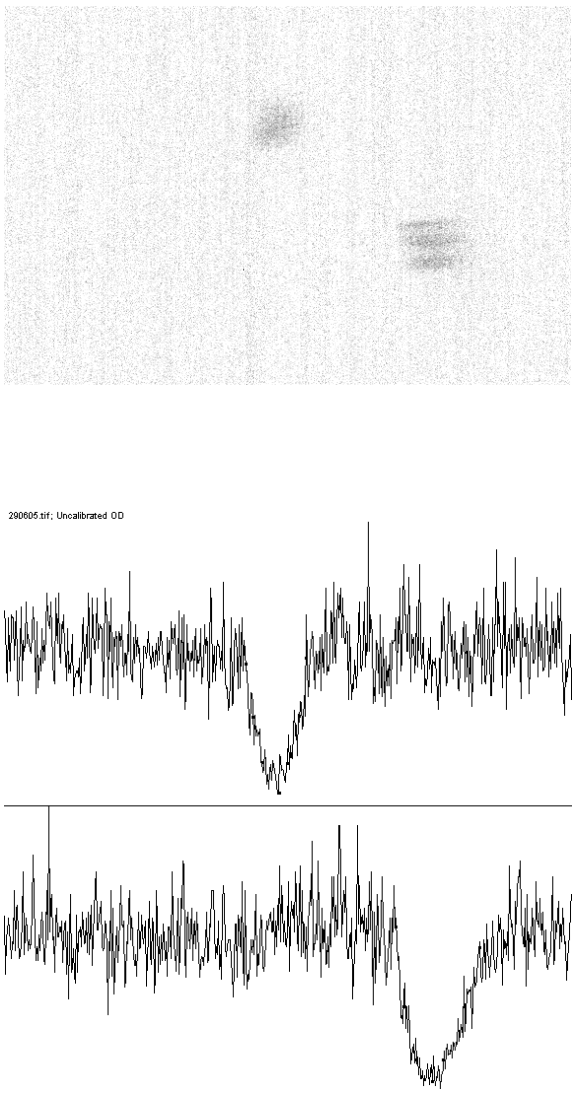


Figure 11: Roquevignon, 29-jun-2000, picture 7
20ps/mm, 19°C, 42 %, 949 hPa, 23:05
Distance: 494.5 m, Green-Red = –97.3 ps

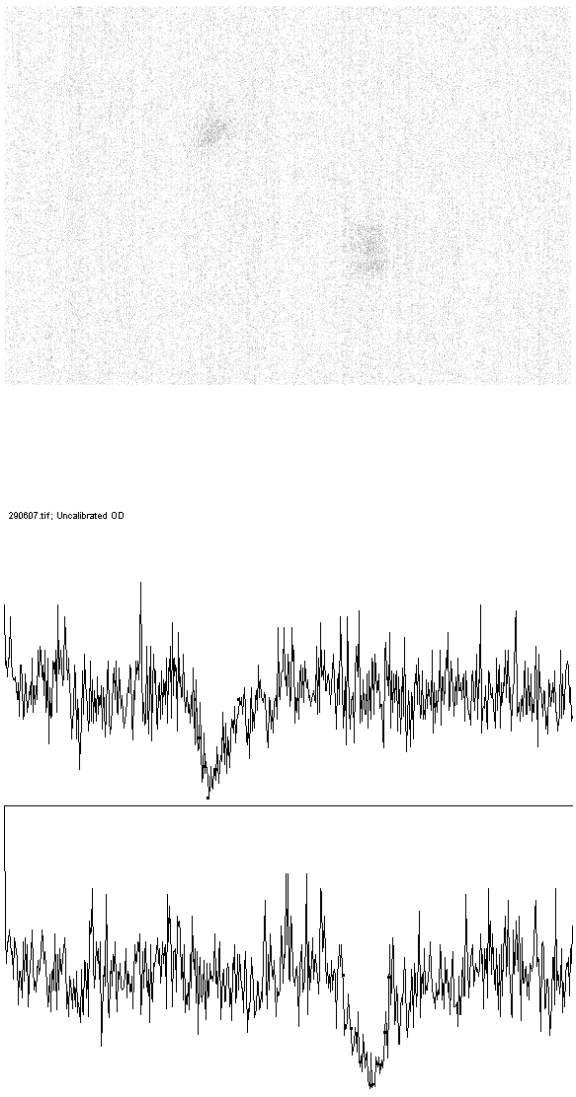


Figure 12: Doublier, 27-jun-2000, picture 2
20ps/mm, 12.5°C, 99 %, 953 hPa, 00:37
Distance: 3423.5 m, Green-Red=+21.2 ps

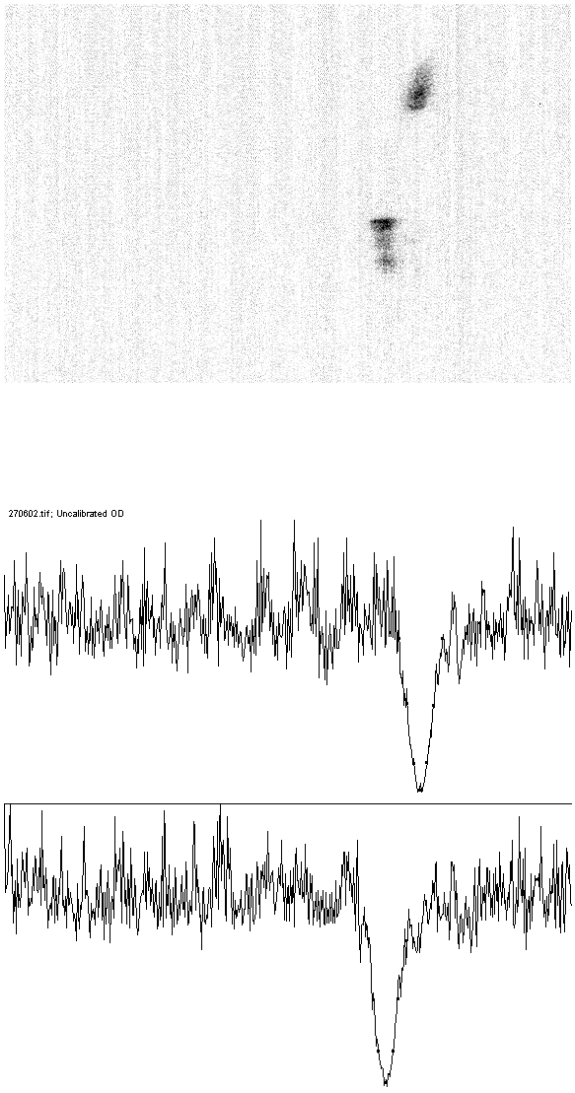
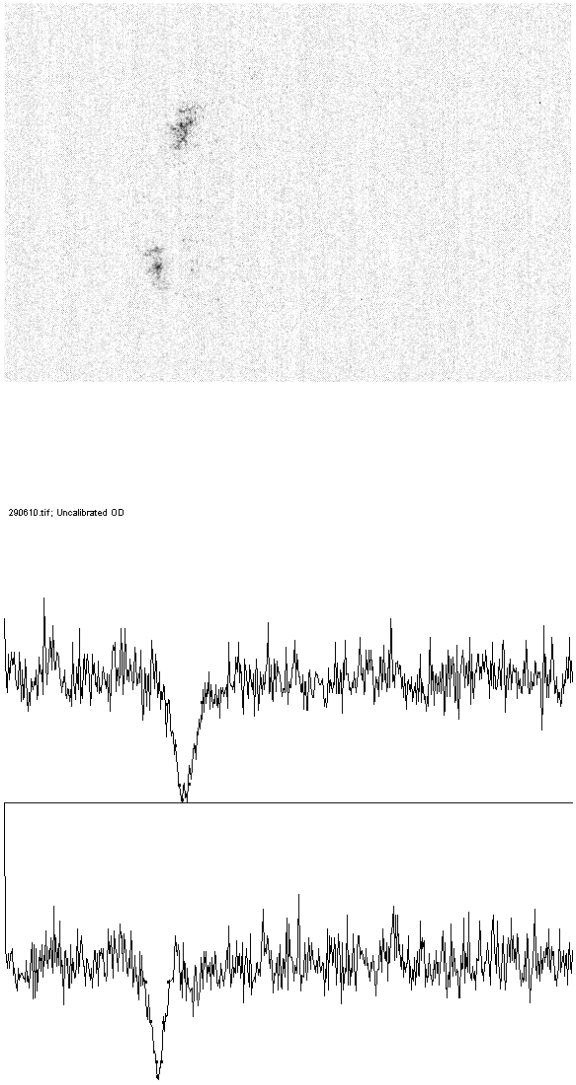


Figure 13: Doublier, 29-jun-2000, picture 10
20ps/mm, 19.0°C, 42 %, 949 hPa, 23:25
Distance: 3423.5 m, Green-Red=+16.5 ps



Target Calibration	Green average	Red average	Green-Red (pix)	ps/pix	Green-Red (ps)	Green-Red-cal (ps)	Date & Time	T° (°C)	Moist. (%)	Pressure (hPa)	Green-Red - average
290601_pix	318,14	510,00	**-191,86**	0,613	**-117,6**	**-1,7**	29/06/00 22:17	19,0	43	949	**-1,7**
290602_pix	189,43	380,14	**-190,71**	0,613	**-116,9**	**-1,0**	29/06/00 22:17	19,0	43	949	**-1,0**
290603_pix	181,43	366,00	**-184,57**	0,613	**-113,1**	**2,7**	29/06/00 22:17	19,0	43	949	**2,7**
290604_pix	206,71	395,71	**-189,00**	0,613	**-115,9**	**0,0**	29/06/00 22:17	19,0	43	949	**0,0**
Mean			**-189,04**		**-115,9**	**0,0**					
Std dev			**2,77**		**1,7**						
Roquevignon											
270604_pix	100,57	262,86	**-162,29**	0,613	**-99,5**	**16,4**	27/06/00 23:05				**-0,4**
270605_pix	220,86	377,43	**-156,57**	0,613	**-96,0**	**19,9**	27/06/00 23:05				**3,1**
270606_pix	296,71	464,43	**-167,71**	0,613	**-102,8**	**13,1**	27/06/00 23:05				**-3,8**
290605_pix	275,71	435,29	**-159,57**	0,613	**-97,8**	**18,1**	29/06/00 23:00	19,0	42	949	**1,2**
290606_pix	67,71	231,43	**-163,71**	0,613	**-100,4**	**15,5**	29/06/00 23:00	19,0	42	949	**-1,3**
290607_pix	209,86	368,57	**-158,71**	0,613	**-97,3**	**18,6**	29/06/00 23:00	19,0	42	949	**1,8**
290608_pix	202,86	365,29	**-162,43**	0,613	**-99,6**	**16,3**	29/06/00 23:00	19,0	42	949	**-0,5**
Mean			**-161,57**		**-99,0**	**16,8**					
Std dev			**3,40**		**2,1**						
Mean 2706xx			**-162,19**		**-99,4**	**16,5**					
Mean 2906xx			**-161,11**		**-98,8**	**17,1**					
Std dev 2706xx			**4,55**		**2,8**						
Std dev 2906xx			**2,04**		**1,2**						
Doublier											
270601_pix	468,29	460,29	**8,00**	1,581	**12,6**	**128,5**	27/06/00 00:37	12,5	99	953	**-4,9**
270602_pix	421,57	387,00	**34,57**	0,613	**21,2**	**137,1**	27/06/00 00:37	12,5	99	953	**3,6**
270603_pix	111,57	73,14	**38,43**	0,613	**23,6**	**139,4**	27/06/00 00:37	12,5	99	953	**6,0**
290609_pix	209,00	178,43	**30,57**	0,613	**18,7**	**134,6**	29/06/00 23:25	19,0	42	949	**1,2**
290610_pix	182,00	155,14	**26,86**	0,613	**16,5**	**132,3**	29/06/00 23:25	19,0	42	949	**-1,1**
290611_pix	270,57	243,29	**27,29**	0,613	**16,7**	**132,6**	29/06/00 23:25	19,0	42	949	**-0,8**
290612_pix	447,43	425,14	**22,29**	0,613	**13,7**	**129,5**	29/06/00 23:25	19,0	42	949	**-3,9**
Mean			**26,86**		**17,6**	**133,4**					
Std dev			**9,13**		**3,6**						
Mean 2706xx			**27,00**		**19,1**	**135,0**					
Mean 2906xx			**26,75**		**16,4**	**132,3**					
Std dev 2706xx			**13,53**		**4,7**						
Std dev 2906xx			**2,95**		**1,8**						

Figure 14: Summary of results for each shot. The "Green-Red-cal" column is the "Green-Red" values minus the average calibration; the "Green-Red-average" column is the "Green-Red" values, minus the average for the target.

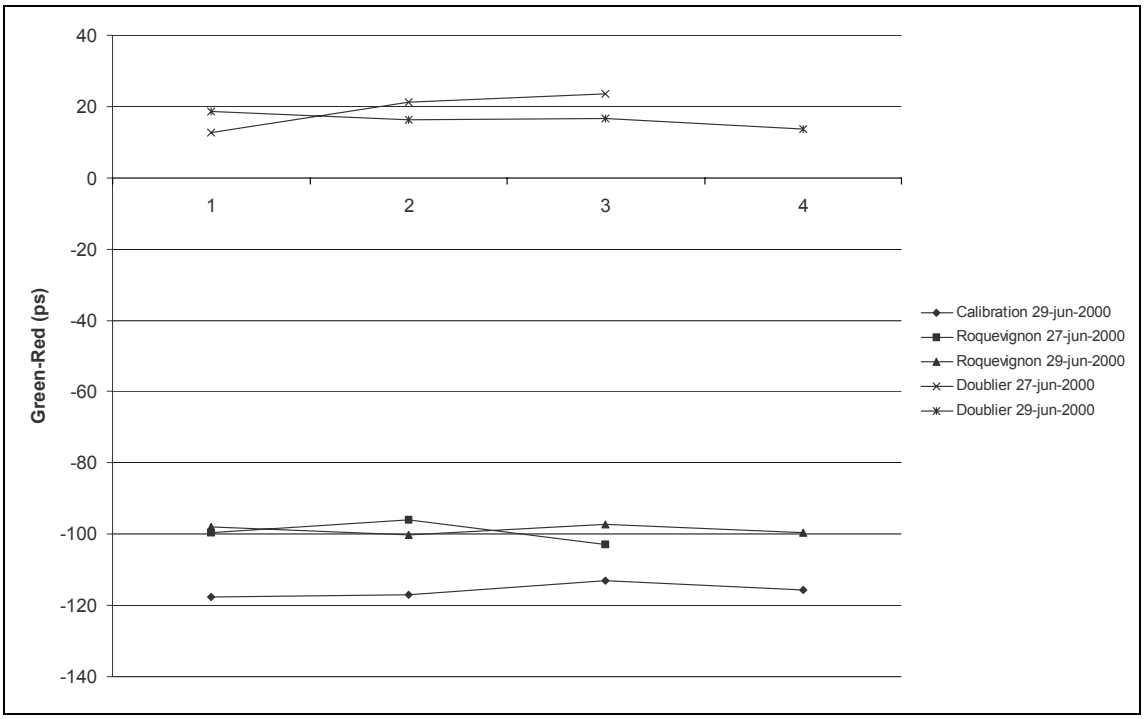


Figure 15: Green-Red differences for each target, the lines connect shots from same sessions.

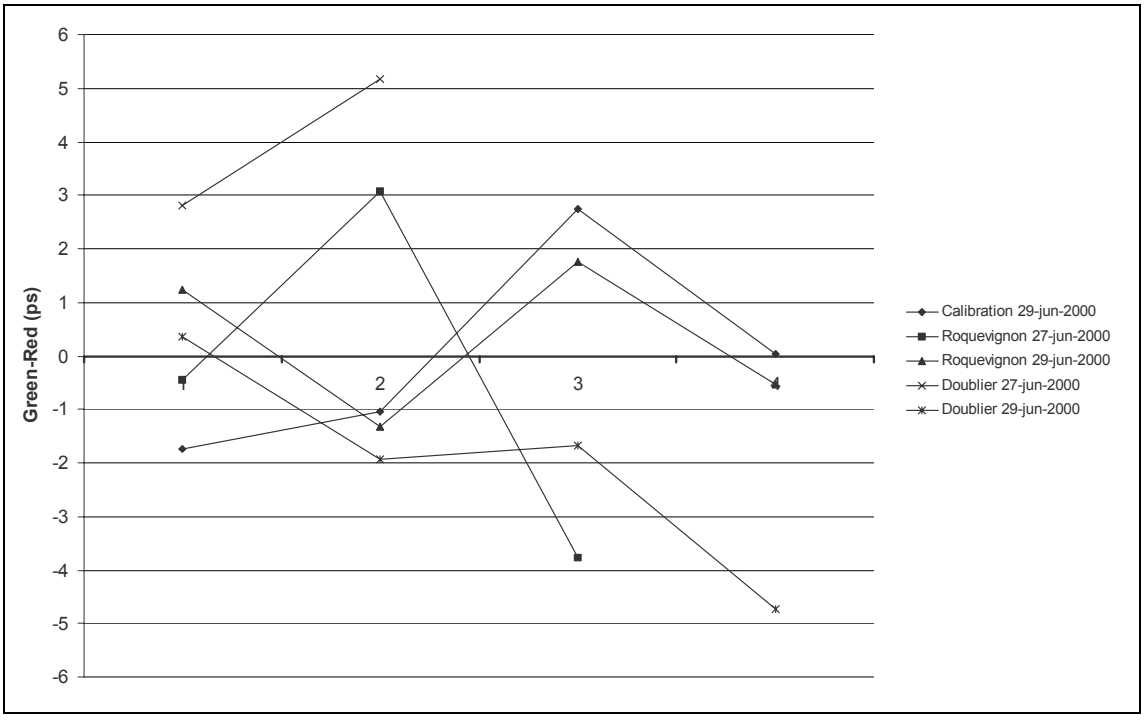


Figure 16: (Green minus Red) minus (average for each target); the lines connect shots from same session.