

CCD UV QE improvement

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ABSTRACT

A combination of oxygen (O₂) soaking, UV flooding and baking permits the removal of "ink-stain" patterns of reduced UV and blue sensitivity observed in [MIT/LL CCDs](#) flat fields. With further optimization of the recipe, significantly improved quantum efficiency (QE) of [e2v CCD44-82 CCDs](#) was also achieved, especially at blue wavelengths. Examples of QE curves and CCD flat fields before and after the sensitization are shown, and crude estimates of the long-term stability of the results are given. A possible explanation is that water vapor contaminates the surface of the CCD and deteriorates the efficiency of the AR coating but is removed by the described procedure. An overview of the instrumental setup, the required materials, and precautionary measures is provided.

Keywords: CCD, detector, quantum efficiency improvement, detector surface, detector sensitization, AR coating.

1. INTRODUCTION

Astronomical detectors should reach optimal performance. One step in achieving this would be a high quantum efficiency. To increase and maintain very high quantum efficiencies with e2v detectors in the UV and blue spectral range a special treatment was developed in the [ESO ODT](#) laboratories. This treatment also serves to improve the cosmetic quality of e2v and other CCD detectors:

Figure 1 is giving monochromatic flat field exposures at a wavelength of 350 nm of an untreated e2v 44-82 blue-optimized anti reflective (AR) coated CCD detector, which shows positive ink-stains and an untreated MIT/LL CCD detector, which shows heavy dark ink-stains.

After the treatment with synthetic air and UV light at 60 degrees centigrade these ink-stains are much weaker or disappear:

Figure 2 shows the results with flat field exposures at a wavelength of 350 nm for the same CCD detectors after the treatment. Now the e2v 44-82 CCD detector has a higher overall quantum efficiency because of the treatment. The whole CCD surface reached the sensitivity of the former positive ink-stains. In case of the MIT/LL Phase 4 CCD detector the black ink-stains have nearly disappeared.

The developed treatment is based on a recipe from Mingzhi Wei (see below) and our experiences with the sensitization of LORAL/Lesser CCDs from 1996. These CCDs needed a UV-flashing in order to reveal their high UV-quantum efficiency before later versions were equipped with a so-called platinum flash gate.

2. INK STAIN REMOVAL

Before treatment:

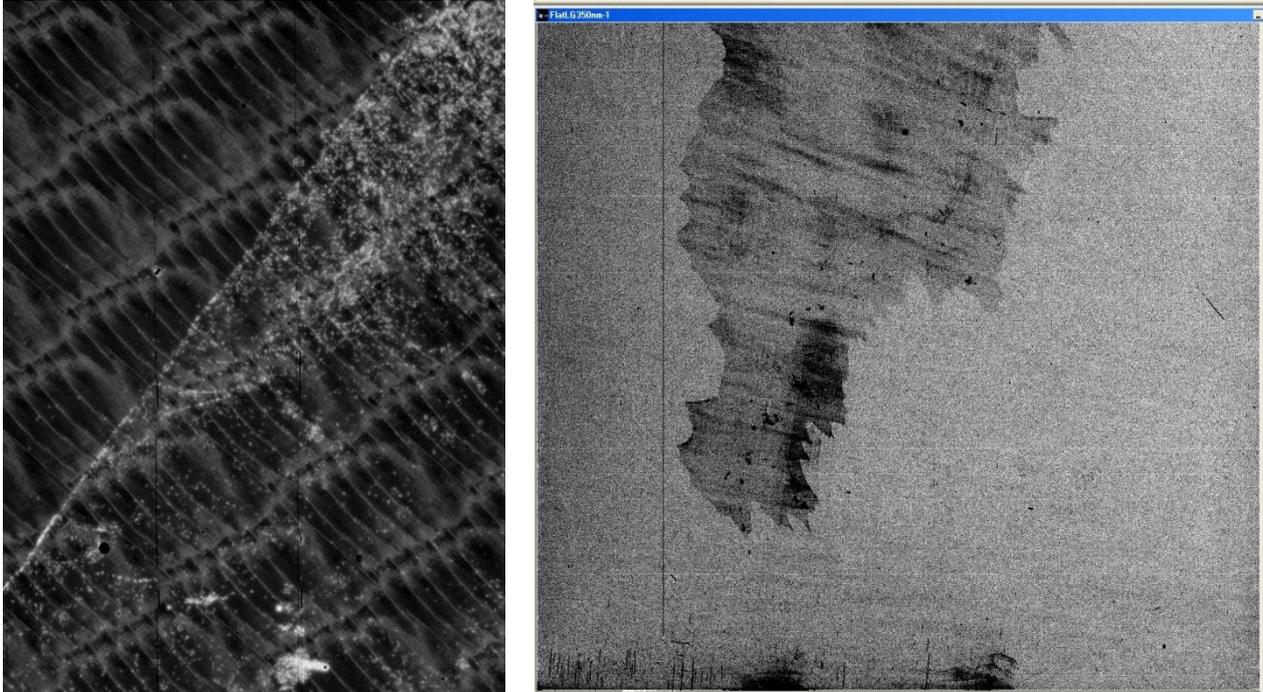


Figure 1: Monochromatic flat fields at 350 nm Left: Untreated e2v 44-82 CCD; Right: Untreated MIT/LL Phase 4 CCD

After treatment:

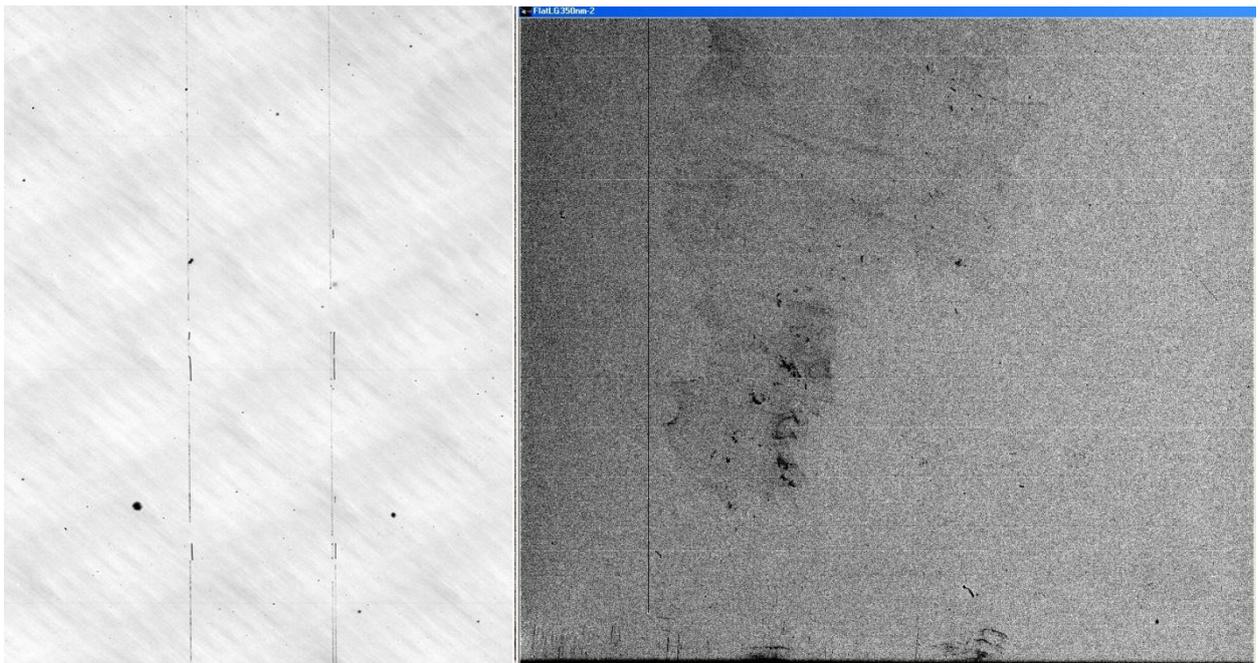


Figure 2: Monochromatic flat fields at 350 nm Left: Treated e2v 44-82 CCD: The overall level reaches the former positive ink stain level; Right: Treated MIT/LL Phase 4 CCD: less ink stains!

Original recipe from Mingzhi Wei

„Soaking the CCDs in O₂ at the same time heating them by a tungsten lamp and then quickly cool them. It works if the CCD is heated in the air: Maybe O₂ from the air is sufficient”.

(Personal communication from April 10th, 2004)

Further developed recipe from ODT

- a. Pump cryostat to approx. 10^{-3} mbar with regeneration of sorption pump up to 90 degree centigrade.
- b. Flush cryostat 2 - 3 times with dry synthetic air (80Vol% N₂, 20Vol% O₂) to 0.8 bar. Between each flushing cycle the cryostat is pumped to approx. 10^{-3} mbar. An over-pressure valve is needed to prevent blowing out the window!
- c. Pumping cryostat and heating CCD to 60 degrees centigrade.
- d. Fill warm cryostat with synthetic air (or pure O₂) to 0.8 bar.
- e. Flood CCD through its quartz entrance window with spectral UV-lamp or simple black light disco lamp for 5-30 minutes. The lamp is positioned as near as possible to the CCD detector (5-20cm).
- f. Immediate pump cryostat and cool to cryogenic temperatures within 6 hours.
- g. Precautions:
 - The use of pure O₂ is dangerous and may cause explosions or corrode bond wires of CCDs and the cryostat, therefore synthetic air is preferred.
 - Do not blow out the cryostat window with overpressure from the gas cylinder! This is prevented by an over-pressure valve and by a very gentle supply of the gas from the pressure cylinder.

3. EXPERIMENTAL SETUP

For the experimental set up the following items are used and carefully assembled (see also Figure 3 for its realization):

- a. Dry oil-free vacuum pumping station up to a vacuum pressure of 10^{-5} mbar.
- b. Safety over-pressure valve with a value of 0.1 bar mounted in the gas supply line.
- c. Dry synthetic air gas (80Vol% N₂, 20Vol% O₂) in a pressure cylinder with a pressure reducer range of 0-5 bar.
- d. Gas pressure manometer with a range of 0 - 1000 mbar in addition to the standard vacuum gauge of the cryostat for measurements of the rough vacuum during the gas fillings.
- e. Oil-free stainless steel ISO KF fittings, valves and flexible pipes.
- f. UV-lamp (preferable: mercury discharge or cadmium spectral lamp) and safety goggles.

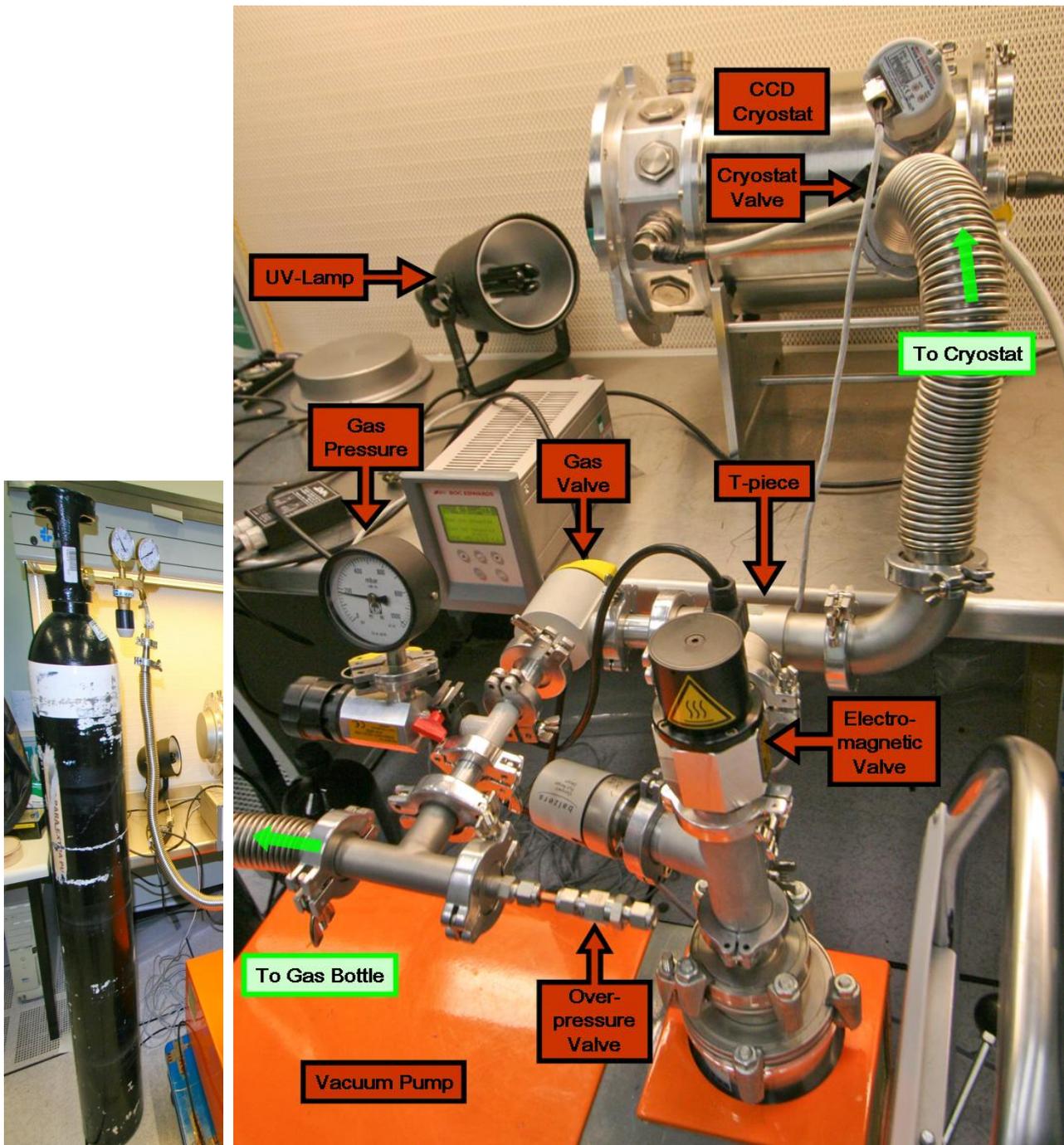


Figure 3: Left: Experimental setup with pressurized gas cylinder with pure dry synthetic air
Right: Experimental setup with CCD cryostat, UV-lamp, vacuum pump and vacuum fittings

4. RESULTS

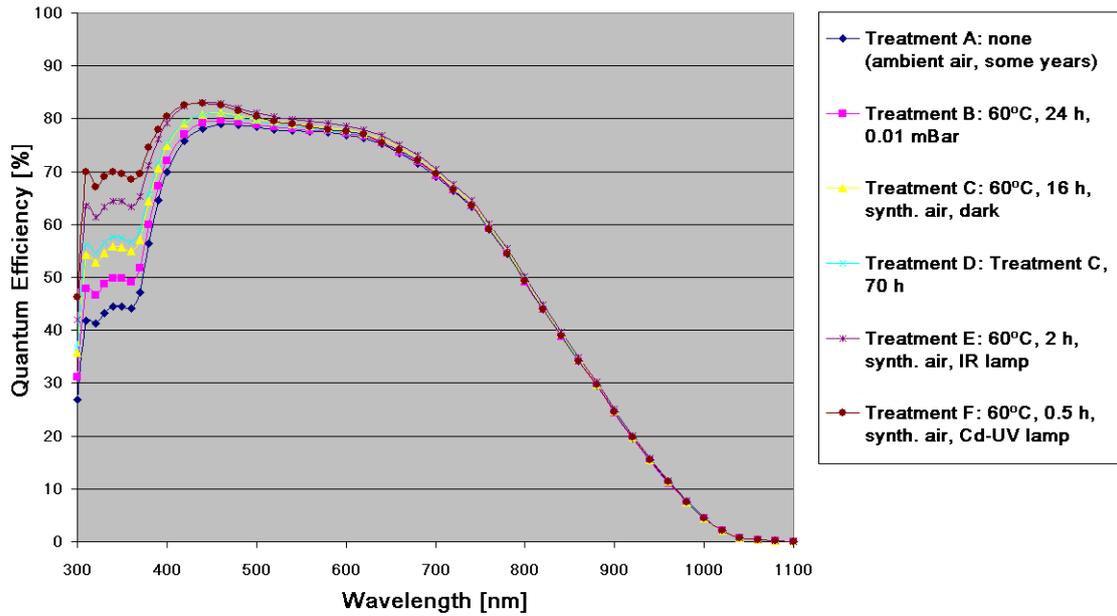


Figure 4: Quantum efficiency results of different treatments of e2v CCD 44-82 broadband AR coated detectors: the maximum quantum efficiency is only achieved with a combination of thermal, synthetic air and UV light treatment as described in this paper

While the QE of e2v 44-82 broadband coated CCDs could be improved in the UV, blue and green wavelength range, the QE improvement of treated MIT/LL CCDs was only marginal over the hole spectral range (see

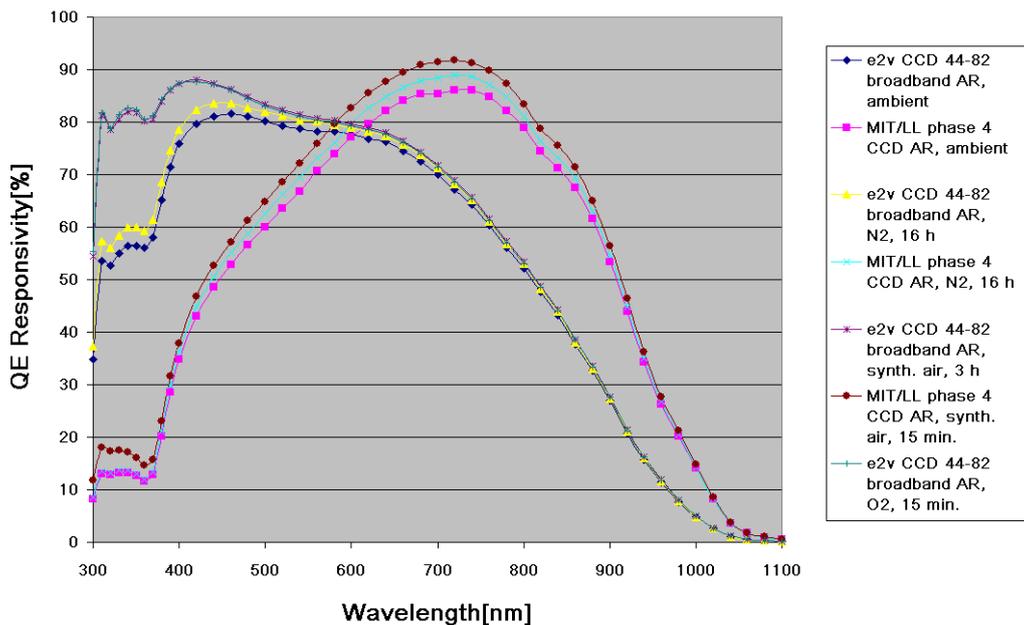


Figure 5: Results of different treatments with a MIT/LL phase 4 and an e2v 44-82 CCD in the same cryostat

Figure 4 and Figure 5). A small QE improvement at the e2v 44-82 CCDs was reached by heating and soaking in pure N₂ gas. An improvement of up to 60 % in the UV and blue spectral range can only be achieved by means of soaking in synthetic air or pure O₂ in combination with light from an UV lamp at 60 degree centigrade detector temperature. The advantage of pure O₂ gas compared with the results achieved with synthetic air is only marginal and not worth the much higher risk. The use of pure O₂ gas is dangerous and special precautions are needed for this.

5. EXPLANATION: CONTAMINATION BY H₂O OR H⁺ MOLECULES

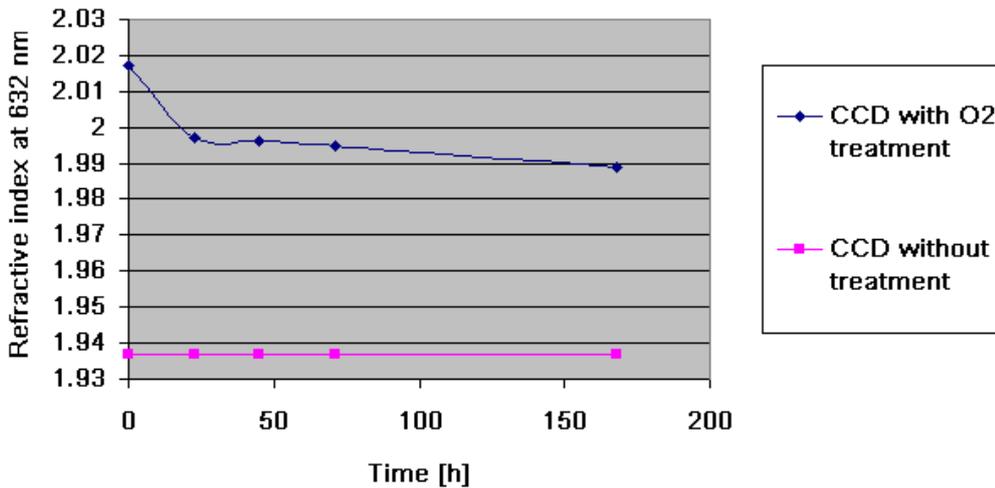


Figure 6: Refractive index measurements of QE improved e2v CCD 44-82 with broadband coated AR

The refractive index of the AR coating of a CCD treated as shown in Figure 6 is higher than the one of an untreated CCD but slowly decreases with time when exposed to normal atmospheric conditions (measurements by SenTech, Berlin). One possible explanation is that, with time and under atmospheric conditions, the AR coating adsorbs H₂O and/or H⁺ molecules, which change the refractive index. Since the AR coating is most important at UV and blue wavelengths, the observed effect is strongest there. This would be consistent with occasional reports that the UV efficiency of CCDs improves after years of operation under high vacuum, when H₂O / H⁺ might be desorbed.

6. LONG-TERM STABILITY

Figure 7 and Figure 8 show the decay of the improved quantum efficiency after the described treatment under different conditions for longer periods.

Provided a good vacuum (10⁻⁵...10⁻⁶ mbar) and cryo-temperatures the high quantum efficiency is stable approx. for 1-2 years. There are even indications for a longer time, because untreated CCD detectors improved their quantum efficiency after being kept under a good vacuum and cryo-temperatures over years without any other measures.

A poor vacuum (approx. 1mbar) and ambient temperatures let decay the effect after approx. 1 month and in ambient air the higher quantum efficiency can only be maintained between hours and a maximum of one week depending on the air humidity.

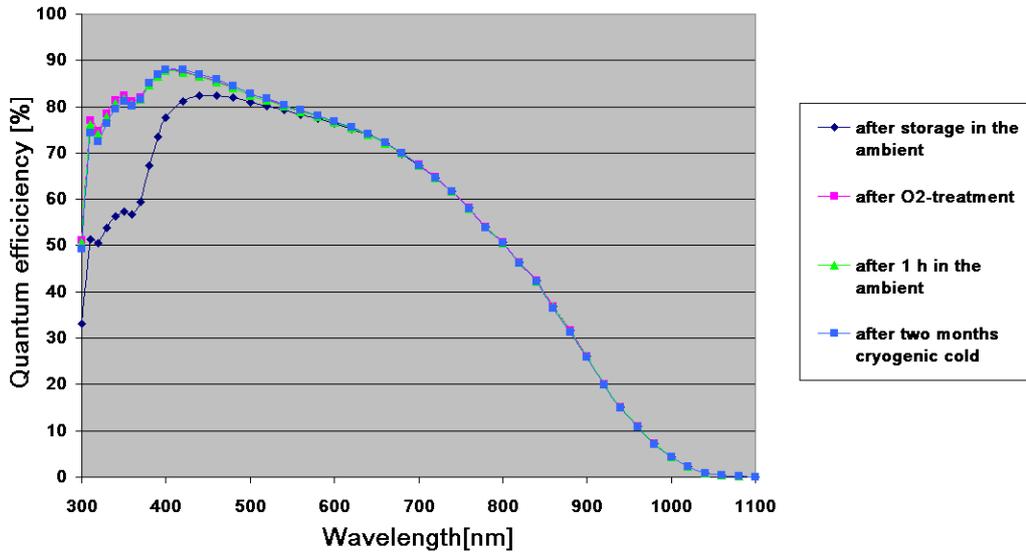


Figure 7: Quantum efficiency of UVES blue e2v CCD 44-82 with UV optimized AR before, directly after and two months after treatment under cryogenic conditions

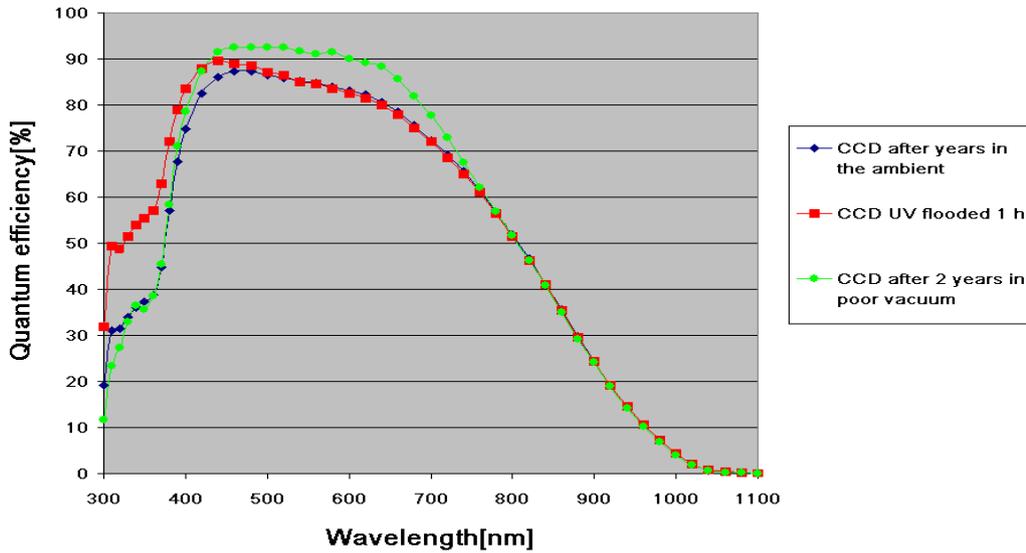


Figure 8: Gas treatment and long-term stability of e2v CCD 44-82 with broadband AR: two years under a poor vacuum (1 mbar and ambient temperature) led to a complete decay of the QE improvement

7. SUMMARY

A reproducible treatment with gas, UV light, and heat was developed and applied to improve QE quantum efficiency and the cosmetic quality of e2v 82-44 and MIT/LL CCD detectors. It is worth and promising to test this procedure with other CCD types in order to achieve optimum performance. The described procedure was already successfully implemented for the CCD detectors of the [FORS](#) instrument at [ESO Paranal](#) (see [1]).

ACKNOWLEDGEMENTS

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REFERENCES

- [1] [DEIRIES, S., "GAS TREATMENT OF CCD DETECTORS ON PARANAL: SHORT MANUAL", ESO DOC.NO.: VLT-MAN-ESO-13121-4244.](#)