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Professional paper

A POSSIBLE THEORETICAL EXPLANATION OF CCD INTERFERENCE PATTERNS

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SUMMARY: Quite high interference disturbance has been noticed in our SBIG ST-6 CCD camera when applied in solar spectrophotometry. This behaviour has been explained quantitatively by the effect of spatial incoherence produced by an extended light source as the sun.

1. INTRODUCTION

A Santa Barbara Instrument Group ST-6 professional CCD imaging camera has been applied for spectrophotometry, at the equatorial solar spectrograph of Belgrade Astronomical Observatory (Kubičela, 1975).

The Belgrade spectrograph is a Littrow-type instrument arranged in the way that the entrance slit is placed in the plane of dispersion. In this case the angle of incidence, α, of the light falling at CCD surface which is perpendicular to the optical axis of the Littrow lens, amounts to about $0.^o6$ (see Figure 2 in Kubičela *et al.* 1994). The spectrograph is directly fed with the solar light - without any projection optics.

The camera yielded spectrograms heavily disturbed by the interference patterns. The interference fringes have been removed by tilting the plane of the CCD receiver for $\Delta\alpha = 4.^o6$ with respect to the optical axis of the spectrograph Littrow lens (Figure 1).

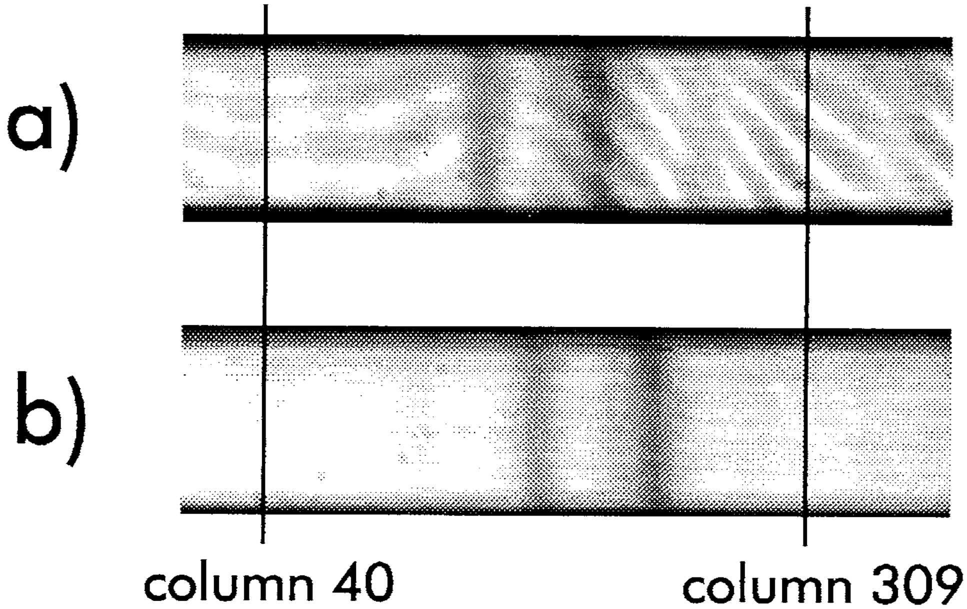

Fig. 1. Solar spectrum around Na I 568.26 nm spectral line taken with SBIG ST-6 CCD camera:
a) In the original arrangement of the spectrograph,
b) with the spectrograph rearanged to remove the interferometric fringes.
The windows comprize 80×375 pixels. The columns 40 and 309 are pointed out (Kubičela *et al.* 1994).

It is interesting to notice that at an intermediate angle $\Delta\alpha < 4.^o6$ the interference fringes can loose some of their contrast without significantly changing their spatial frequency. Experiments with much higher values of $\Delta\alpha$ than was applied were not possible because of the camera construction.

In this paper we present a possible theoretical explanation of this behaviour of interference patterns in our CCD camera.

2. THEORY

To explain this behavior of our CCD camera we consider a spatially incoherent extended light source (Sivuhim 1980) that illuminates an interference medium between incidence angles from i to $i + \Delta i$. When the displacement of two interference patterns (related to the beams at i and $i + \Delta i$) is $\frac{\lambda}{2}$ the maxima from one beam will coincide with the minima from other one and the interference fringes will not be observed.

Adopting the model of a thin plate to which we attribute the equivalent thickness h, the interference minima of the beam at i will be observed when

$$\Delta = 2h\sqrt{n^2 - \sin^2 i} = m\lambda,$$

where n is the equivalent refractive index at the plate and m is an integer. In our case $\Delta i = \phi_\odot U$, where $\phi_\odot$ is the solar angular diameter and U is the magnification of the spectrograph, the interference pattern displacement is determined by

$$\frac{\partial\Delta}{\partial i} = \frac{\partial\Delta}{\phi_\odot U} = h\frac{\sin 2i}{\sqrt{n^2 - \sin^2 i}}.$$

So, the minimum angle at which the interference fringes will cancel is

$$i_{min} = \frac{1}{2}\arcsin(\frac{\lambda n}{2h\phi_\odot U}),$$

where we substituted $\frac{\lambda}{2}$ for $\partial\Delta$ and neglected $\sin^2 i$ with respect to n^2.

We estimate the equivalent plate thickness in the conditions at the normal incidence ($i = 0^o$) using the distance x between two successive (dm=1) minima:

$$h = \frac{x}{2n},$$

so, the i_{min} is given by

$$i_{min} = \frac{1}{2} \arcsin(\frac{\lambda}{dx} \frac{n^2}{\phi_\odot U}). \qquad (1)$$

Assuming n=1.5 and using that $\phi_\odot = \frac{1}{2}^o$, U=1, λ=0.5 μm, x=20 pxl (1 pxl=27 μm) and substituting these values in equation (1)

$$i_{min} \approx 7^o$$

This angle is near to our experimental value of $\alpha + \Delta\alpha = 5.^o2$. So, we believe that the fringes in our spectrograph disappeared by tilting the CCD due to the effect produced by the extended light source.

3. CONCLUSION

The interference fringes originating near the surface of the CCD chip have been successfully removed by increasing the light incidence angle. This behaviour has been explained by the effect of spatially incoherent light source.

However, lack of our detailed knowledge about the structure of SBIG ST-6 CCD chip prevents us to prescribe a more realistic meaning to what we call "interference medium" and to what we estimated the equivalent thicknes h. This might be any transparent layer incorporated in the CCD chip in front of the light sensitive elements (pixels) or even the protecting glass window at some distance from the chip. More research would be needed to identify that medium as an optical structure or a physical layer able to produce the observed interference. It would be also interesting to see wether our approach (nonperependicular illumination of the active CCD area) works in some other CCD receivers sensitive to interference fringes.

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ЈЕДНО МОГУЋЕ ТЕОРЕЦКО ОБЈАШЊЕЊЕ ИНТЕРФЕРЕНЦИОНИХ ФОРМАЦИЈА КОД CCD КАМЕРЕ

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Стручни рад

Приликом примене SBIG ST-6 CCD камере у спектрофотометрији Сунца примећени су изразито јаки интерференциони поремећаји. Овакво понашање камере квантитативно је објашњено просторном некохеренцијом која се јавља код нетачкастих извора светлости као што је Сунце.