Table I. Calibration Factors of the METEOSAT-VIS-Channel (6-bit Data)

Target Type	Calibration factors [W m^{-2} sr^{-1} count^{-1}]
Land surface	5.16
Stratocumulus	5.40
Atlantic Ocean	9.60
Mediterranean Sea	8.00

craft immediately before and after each comparison measurement.

The correction for the atmosphere remaining above the aircraft was calculated with a computer program by Quenzel[2] which solves the radiative transfer equation by the method of successive orders of scattering. The computation was done for five wavelengths. Spectral correction factors were obtained by taking the ratio of the radiance emerging from the atmosphere in the direction of METEOSAT and the upwelling radiance in flight level in the same direction. The wavelength integration was done by weighted averaging of the spectral correction factors. It turned out that for low solar zenith angles the resulting correction factors are more or less independent of the atmospheric turbidity. This was the case for all measurements.

All measurement errors are known to be below ±1%. The error of the atmospheric correction factors may be ±1%. Together with the ±3% absolute calibration error, an overall accuracy of better than ±5% seems to be realistic. This holds for the comparison measurements but not for the METEOSAT measurements as shown below.

Comparison measurements were made over three different types of target: a land surface in Spain, a stratocumulus layer over the Atlantic between Portugal and Morocco, and three cloudless ocean areas. The latter were the Atlantic Ocean between Portugal and Morocco (north of the stratocumulus layer) and the Mediterranean Sea between Menorca and Marseilles and between Sardinia and Tunis. The land surface southeast of Madrid, known as La Mancha, was identified by means of Landsat images to be rather homogeneous. Land use in this woodless area is agricultural with wheat, corn, and sunflowers. This area was measured twice on successive days and the resulting calibration factors differ by <0.1%. The stratocumulus layer was almost closed (7/8 to 8/8). The Atlantic site had visually much less turbidity than the two Mediterranean sites. Due to the 6-bit resolution of the METEOSAT-VIS-channel only rather high signals can be measured with an accuracy of ±5% or better. This was the case for the land surface and the stratocumulus layer. The cloudless ocean sites, however, can only be measured with an accuracy of ~±20% because of the very low reflectance factor of water outside the sunglint, which yields virtually a measurement of the atmospheric path radiance. The spectral dependence of the path radiance varies from λ^{-1} to λ^{-4} according to the atmospheric turbidity. Because of the triangular spectral sensitivity of the METEOSAT-VIS-channel, more radiance is needed to produce one METEOSAT count in a very clear atmosphere than in a dusty atmosphere. Consequently the calibration factor is higher. According to these two effects, the difference of the calibration factors of the two Mediterranean sites of 5% may be caused by the 6-bit resolution and is neglected in Table I, whereas the difference of 20% between the Atlantic and the Mediterranean sites may be due either to the different turbidity or to the 6-bit resolution or, most probably, to both.

Table I shows the results of the original 6-bit data. For 8-bit data, which are routinely produced from the 6-bit data by ESOC by adding two random bits, the calibration factors must be divided by 4. A quick look on our recent spectral measurements indicates the ratio of the calibration factors of the ocean and the land surface to be ~1.5, which lies well within the given accuracy range.

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References:

1. A. K. Ångström and A. J. Drummond, Appl. Opt. 1, 455 (1962).
2. H. Quenzel, "Computation of Luminance and Color Distribution in the Sky," in *Daylight Illumination-Color-Contrast Tables*, M. R. Nagel, H. Quenzel, W. Kweta, and R. Wendling, Eds. (Academic, New York, 1978).

Chopper technique for measuring a delayed fluorescence spectrum superimposed on a excitation spectrum

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Any fluorescence measurements involve the use of a pump source (lamp, laser), a detector, and one or more devices to separate the exciting radiation from the fluorescence such as optical filters, monochromators, or spectrometers. In cases where the optical excitation of a defect or impurity in a crystal is followed by a nonradiative decay toward the emission level, it is relatively easy to separate optically the pump wavelength from the fluorescence wavelength and to eliminate all the problems of scattered light, stray light, and ghosts from gratings. There exists however the situation where the pump and fluorescence wavelengths are comparable with each other, as is the case, for example, for rare earth or transition ions in crystals, zero phonon lines.

These technical problems are difficult to solve: one may encounter prohibitive detector saturation or be left to measure very small signals over a large unwanted background, especially if one does not possess sophisticated high-resolution instruments. These situations are even worse when one is studying forbidden optical transitions (as will be the case here) for which high optical excitation intensities are mandatory.

We shall describe a simple chopper technique that eliminates these problems in those cases where the fluorescence decay time is of the order of 20 μsec or longer. This technique has been successfully used to measure excitation and emission spectra and decay time behavior of isolated and pairs of Cr^{3+} in $GdAlO_3$ when excited in their lowest energies transitions.[1,2] For the sake of simplicity we shall describe in detail only the system for measuring excitation spectra (Fig. 1). The basic element is a high speed mechanical chopper (PAR 192) having a maximum rotational range of 0–100 rps and running in air. It uses a specially designed aluminum wheel shown in Fig. 2. Contrary to all wheels commercially supplied, this one has an odd number of radial apertures, and its inner parts have a smaller angular aperture size (~20° ± 3′) than the outer part (36° ± 3′). As the wheel is symmetric, balancing was not necessary. In the conventional technique it is usual to chop only the exciting beam and to detect the fluorescence (plus scattered light) at the same frequency and at the same time (zero phase difference). In our system (Fig. 1) the exciting beam is focused on the left side of the wheel and chopped by

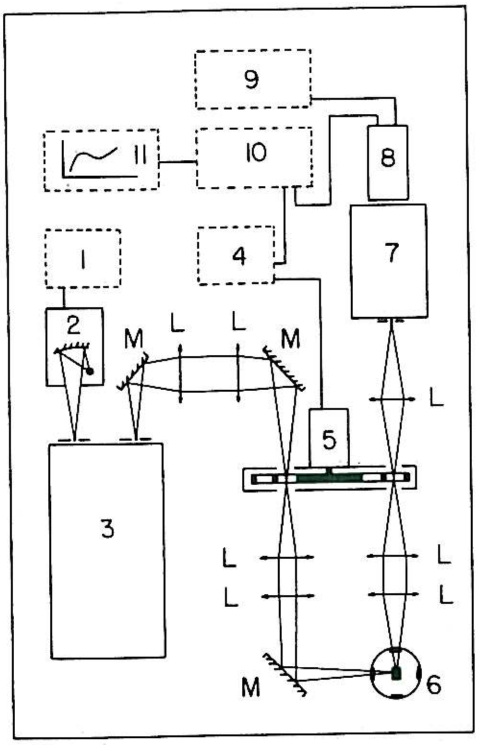

Fig. 1. Experimental setup for measuring excitation spectrum with high resolution: (1) power supply for Xe lamp (Oriel 6124); (2) Xe lamp 150 W $f/8$ (Oriel 7340); (3) Jarrell-Ash 50-cm monochromator (82020); (4) power supply for chopper (PAR 192); (5) chopper (PAR 192-93); (6) liquid helium cryostat (Janis Supervaritemp); (7) Bausch & Lomb monochromator (33-86-79); (8) photomultiplier (EMI 9559QB, Ext S20); (9) power supply for photomultiplier (Keithley 244); (10) lock-in (PAR 5204) or boxcar (PAR 160); (11) recorder (W + W 312); (L) convergent lens (Oriel); (M) Al mirror (Oriel).

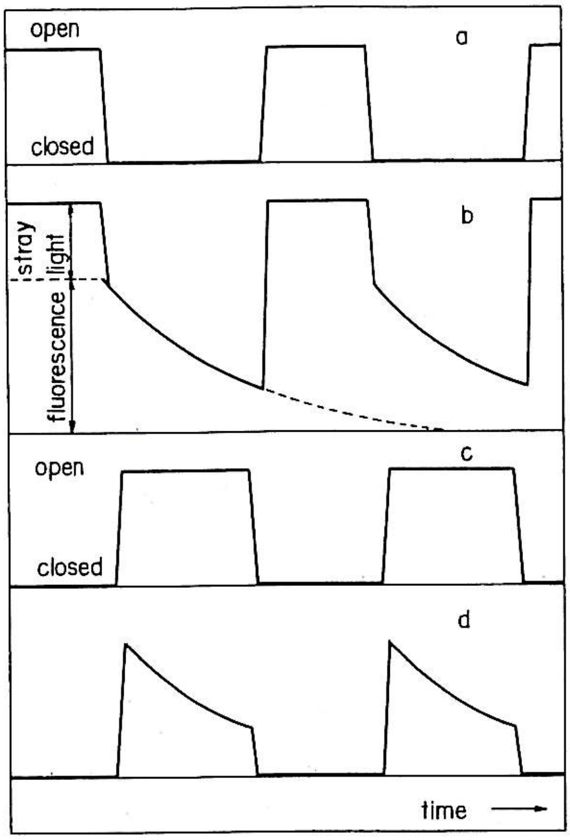

Fig. 3. Schematic time sequence of the events (see also Figs. 1 and 2): (a) excitation path; (b) luminescence plus stray light signal as it would be measured just after the crystal; (c) fluorescence path; (d) luminescence signal only, detected according to the scheme of Fig. 1.

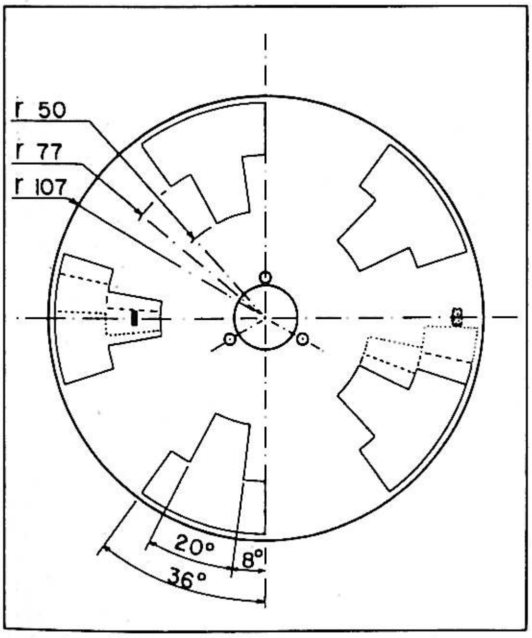

Fig. 2. Design of the chopper wheel and positions of the exciting beam (left) and emission beam (right). Three positions of the wheel are shown: (—) exciting path open, emission path closed; (---) beginning of closing sequence of the exciting path, emission path still closed; (···) exciting path closed, beginning of the opening sequence of the emission path.

the inner slots, while the fluorescence is focused on the right side of the wheel and is chopped during its decay by the outer slots at the same frequency but with a mechanical phase shift of 180°. In this way all the scattered or stray light coming from the exciting beam and dying with it is eliminated; the detector will only see the true luminescence. The difference in angular aperture for the exciting and fluorescence paths was made to take into account the finite height (~4 mm) of the focused beams; in this way one path is open (or, respectively, closed) only when the other is closed (or, respectively, open). This behavior is explained in Fig. 2, where we show schematically the position of the apertures for three different times, and in Fig. 3, where the time sequence of events is shown at different places in the optical setup: (a) at the left side of the chopper, (b) in between the cryostat and the right side of the chopper, (c) at the right side of the chopper, and (d) at the detector. As the luminescence is detected during its decay, a slight reduction of the dc fluorescence signal given

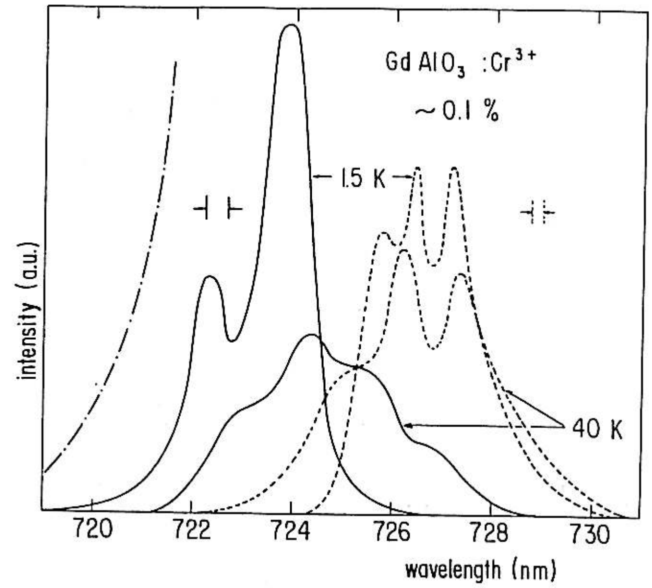

Fig. 4. Solid line indicates the excitation spectrum of the $^4A_2 \rightarrow {}^2E$ transitions of isolated Cr^{3+} in $GdAlO_3$ measured 1.5 and 40 K with the setup of Fig. 1. The emission monochromator was set at 727 nm with a halfwidth of 3.2 nm. --- Luminescence spectrum of the $^2E \rightarrow {}^4A_2$ transitions of isolated Cr^{3+} in $GdAlO_3$ measured at 1.5 and 40 K with a similar setup. The excitation monochromator was set at 724 nm with a halfwidth of 3.2 nm. -·- Tentative measurement of the same spectrum using a conventional technique.

by the lock-in is expected as compared with the conventional technique. Moreover any variation of the decay time will modify the intensity in the same way, and one should be cautious in comparing spectra, in particular those recorded as a function of temperature.

The use of this technique is limited by the decay time of the fluorescence. It is difficult to give a lower limit for it since this number will depend essentially on the height of the beams focused on the wheel, the number of apertures, and the speed of the chopper. Typically, using a 100-rps speed, 21 slots (~80/4° apertures), and 1-mm diam focused beams, it would be possible to detect in excellent conditions any fluorescence whose decay time is longer than 50 μsec. The fluorescence spectra can be measured with the same equipment without any modification. In this case the exciting monochromator will be fixed at a certain wavelength, and the spectrum is recorded by scanning the emission monochromator without any perturbation from the exciting beam.

Decay time measurements can also be performed by replacing the lock-in analyzer by a boxcar integrator. The beginning of the decay will be lost, but this can be minimized by using a sharply focused exciting beam to reduce the difference of the angular apertures of the slots. A system using two high speed choppers, whose phases were controlled by a phase shifting network, has already been described by Ingersoll.[3] We have used this technique with the components shown in Figs. 1 and 2 for measuring, as a function of temperature, the almost superimposed excitation and emission spectra of the forbidden transitions $|^4A_2\rangle \leftrightarrow |^2E\rangle$ and $|^4A_2{}^4A_2\rangle \leftrightarrow |^4A_2{}^2E\rangle$ of isolated, respectively, pairs of Cr^{3+} in $GdAlO_3$.[1,2] The decay times at liquid helium temperature are, respectively, 10 and 1 msec, and we used a chopping frequency of 300 Hz. The height of the focused beam at the wheel was of the order of 4 mm. The results are shown in Fig. 4. The excitation spectra (solid line) that reflect the absorption spectra (α_{max} = 0.3 cm^{-1}) have been recorded with the emission monochromator set at 727 nm with a halfwidth of 3.2 nm. The emission spectra (dashed line) have been recorded by interchanging the two monochromators (Fig. 1). The excitation monochromator was set at 724 nm with a halfwidth of 3.2 nm. The dotted line represents an attempt to use a conventional signal beam technique. As can be seen in the figure, the new technique really allows one to scan through the spectra without any interference from scattered or stray light.

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References

1. H. C. Basso, M.Sc. Thesis, U. São Paulo, Instituto de Física e Química de São Carlos, São Carlos (SP) Brazil (1980).
2. H. C. Basso, M. A. Aegerter, and H. Scheel, to be published.
3. K. A. Ingersoll, Appl. Opt. 15, 61 (1976).

Three-dimensional TV system

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The goal of 3-D TV is an attractive one. In principle, many of the techniques which in the past have been applied to stereoscopic photography could be adapted to TV, and an excellent review of such adaptations has been given by Valyus.[1]

Use of two separate cameras, transmission channels, receivers, and displays for the left- and right-eye views is straightforward and can yield good 3-D effects if the displays are viewed in some form of Brewster or related stereoscope. However, such a system suffers from a number of disadvantages: extravagance in broadcasting bandwidth, a doubling of the display equipment required, restriction to a single viewer in a fixed viewing position, and the need for exact matching of the optical and electronic characteristics of the two picture-generating subsystems if false stereo effects are to be avoided. Split-screen presentation of stereo pairs,[2] while making no extra demands on bandwidth, again only allows very restricted viewing arrangements unless projection systems are used, combined of course with a loss in effective picture area. Raster or parallaxogram arrangements[3] make formidable demands on the stability of the displayed picture.

Earlier anaglyph proposals[1,4,5] have been revived in slightly different form by Nithiyanandam and Rajappan.[6] A modified picture tube is used to produce a yellow and blue pair of images that are viewed through appropriately colored goggles. Specialized equipment is thus required but no strong constraints are set on either the number or positions of viewers.

Another early proposal,[1,7,8] that left- and right-eye views be encoded in successive odd- and even-line fields of the normal TV frame, has recently been put forward again for color TV by Zammit and Swegle.[9] In the U.S. system the transmitted signal of normal bandwidth would consist of temporally alternating 1/60-sec duration left- and right-eye views, each containing ~252 lines. At the receiver a synchronous switch would send these fields alternately to two