MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

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APPLICABILITY OF SOME PHOTODETECTORS TO IODINE LASER PULSES ($\lambda = 1.3\,\mu$)

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Abstract

Vacuum photodiodes, solid-state photodiodes and an image converter camera were examined with respect to sensitivity at the wavelength of the iodine laser ($\lambda = 1.3\,\mu m$).

It was found that selected vacuum photodiodes with S-1 cathodes may have sufficient sensitivity in the infrared region around 1.3 μm. The image converter camera which has also S-1 characteristic shows, however, rather poor response to the infrared light. Solid-state photodiodes, whose rise time is generally far slower than that of the laser pulses, are unavailable for this purpose.

I. Introduction

In context with the recently developped high-power, short-pulse iodine laser (wavelength λ = 1.315 μm, pulse duration $\tau \lesssim$ 1 ns), detectors for measuring such a pulse are urgently needed. Therefore, we have examined several kinds of commercially available photo-detectors (vacuum photodiodes, semiconductor photodiodes and an image converter camera) with respect to sensitivity and time resolution at the relatively long wavelength of this laser.

II. Tested Samples

The photosensitive detectors under test were two kinds of biplanar vacuum photodiodes (Valvo XA-1oo3 and ITT F-4ooo) which have nominally S-1 characteristics, a Germanium photodiode (Valvo APY-12), two silicon photodiodes (HPA-422o) and an image converter camera with S-1 characteristic (Electro Photonics). Nominal qualities of them are listed in Table 1.

III. Testing Procedures

The tests have been performed with the arrangement shown in Fig. 1a. The light source is a standard tungsten lamp (Osram Wi-17) with a temperature of 25oo ^{o}K. The light flux, analized by a monochromator, is fed onto the detector to be tested. Some filters are occasionally inserted into the light path to eliminate undesirable spectra. The electrical signal corresponding to the mechanically-chopped light flux is amplified and displayed on an oscilloscope. In case of the image converter camera, it is operated in "focus mode" (continuous mode), and the light intensity produced on the screen of the image intensifier is detected by a photodiode (Fig. 1b).

IV. Results

a) Semiconductor Diodes

Results on Germanium diodes are shown in Fig.2, with typical spectral sensitivity curves from a data sheet (all sensitivity curves are normalized with respect to peak sensitivity). Although the Germanium diode has sufficient response for the wavelength of 1.3 μm, its frequency response is very slow according to Table 1. Therefore, it cannot resolve short laser pulses.

The frequency response of the silicon diode is better than that of Germanium, but is still very slow compared with the laser pulse. Moreover, its spectral response to wavelengths greater than 1.2 μm is intolerably low, as shown in Fig.3. Measurements towards longer wavelengths were impossible because of the high noise level.

b) Vacuum Photodiodes

Two samples of the ITT F-4000 and two samples of the Valvo XA-1003 photodiodes, all of which have nominally S-1 characteristics and good time-response (τ_r = 250 psec), were tested. The results are shown in Fig.4. Up to 1.0 µm every sample has a wavelength response which is very close to the curve of a data sheet, but at longer wavelengths there appear great differences among individual samples. The sensitivity varies more than one order of magnitude at 1.3 µm from sample to sample. The tube which gives highest output is one of the Valvo's. It gives an output at 1.3 µm only two orders lower than its peak value at 0.8 µm, such a value being one order higher than the extrapolated catalogue value.

c) Image Converter Camera

This camera has also nominally S-1 characteristic photocathode. Measured results show, however, that the spectral response decreases very strongly with increasing wavelength. At 1.1 µm its sensitivity is 10^{-3} less than the peak value (see Fig.4). At 1.3 µm the sensitivity was so low that it could not be measured with the light source used here.

V. Discussion

The four vacuum photodiodes differ in sensitivity at the tail of the S-1 characteristic curve. The best one gives at 1.3 µm an output only 10^{-2} lower than the peak, but the others give 10^{-3} lower values. The background noise level is also individual. The reason why the output differs 10 times or more around 1.3 µm is not yet clear, but it can be supposed that the cathode material (Cs-O-Ag compound) has a rather complicated energy-band structure and that the surface states and the energy levels are widely changed at its production-, aging-, and activation-processes /1/. In a critical region for photoemission, such sort of little deviation of the energy band affects the quantum efficiency. Therefore, if those tubes are used for 1.3 µm light, one should try to select the best one among many similar tubes.

The image converter camera shows a much more tragic response. The cathode may be damaged by an infrared light flux which is sufficiently high to produce a detectable image. The low sensitivity of the cathode may also be a result of the production process, but it seems to be a more essential characteristic in this case. It may be due to the thickness of the photocathode, which is made very thin in this case to secure the sharpness of the picture. Since the sensitivity of the cathode is too low to take pictures at a wavelength of 1.3 µm it is suggested to make use of the second harmonic light (6576 A) which is produced by passing the original light of 1.3 µm through a nonlinear optical element.

From the data on the semiconductor photodiodes it is clear that their low frequency response makes both of them unsuitable for the detection of short iodine laser pulses. Reference /2/ shows, however, that a germanium avalanche photodiode for infrared light, which has very fast rise time, has been recently developped. Such a diode may be in future applicable to the iodine laser pulse.

References

/1/ S. Larach ed. "Photoelectronic Materials and Devices", van Nostrand Co., Princeton N.J., U.S.A. (1965) p. 2o7

/2/ H. Melchior, J. Luminescence 7 (1973) 39o.

Substance (Material)	Maker and Specific Name	Max. Response at:	Risetime or Frequency Limit	Sensitivity (max.)
Ag-O-Cs photo cell	Valvo XA-1oo3	o.8 μm	o.25 ns	2 μA/lumen
Ag-O-Cs photo cell	ITT F-4ooo	o.8 μm	o.25 ns	2 μA/lumen
Ge-semiconductor diode	Valvo APX-12	1.43 μm	5o kHz	1oo μA/lumen
Si-semiconductor diode	HPA-422o	o.8 μm	5o kHz	16o μA/lumen
image converter camera	Electro Photonics	o.8 μm	5 ps	13o μA/lumen

Table 1 Nominal specifications of diodes and an image converter camera to be tested

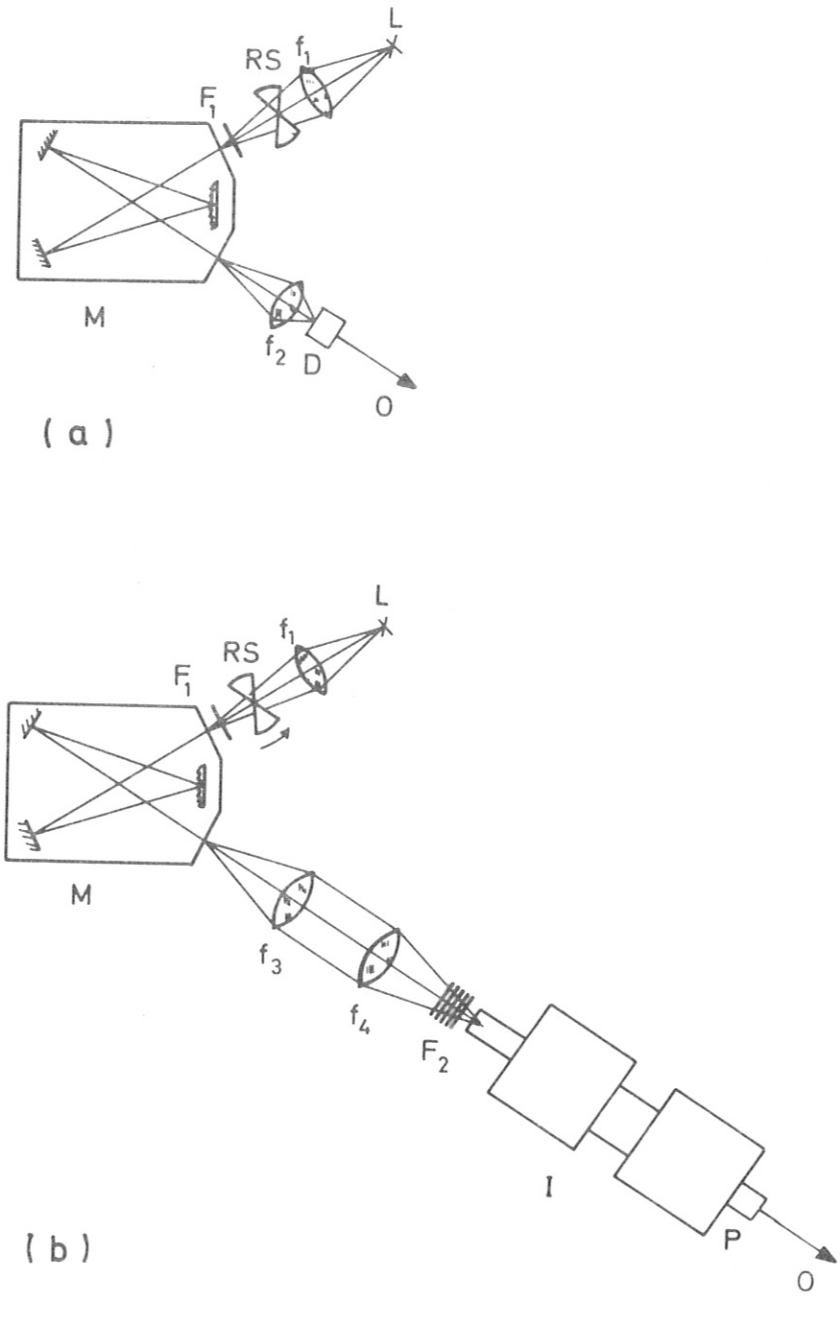

Fig.1 Schematic arrangements of apparates, (a) for photodiodes, and (b) for an image converter camera. Notation on the figure is as follows: D = diode, f_1 = 1oo mm, f_2 = 5o mm (used only for Si- and Ge-diodes), f_3 = 4oo mm, f_4 = 4oo mm, F_1 = filter (GG 515, RG 715, Si), F_2 = neutral filter, I = image converter camera system, L = tungsten lamp (Wi 17), M = monochromator (Mc Pherson: 3o cm), O = oscilloscope, P = photodiode, and RS = rotating sector.

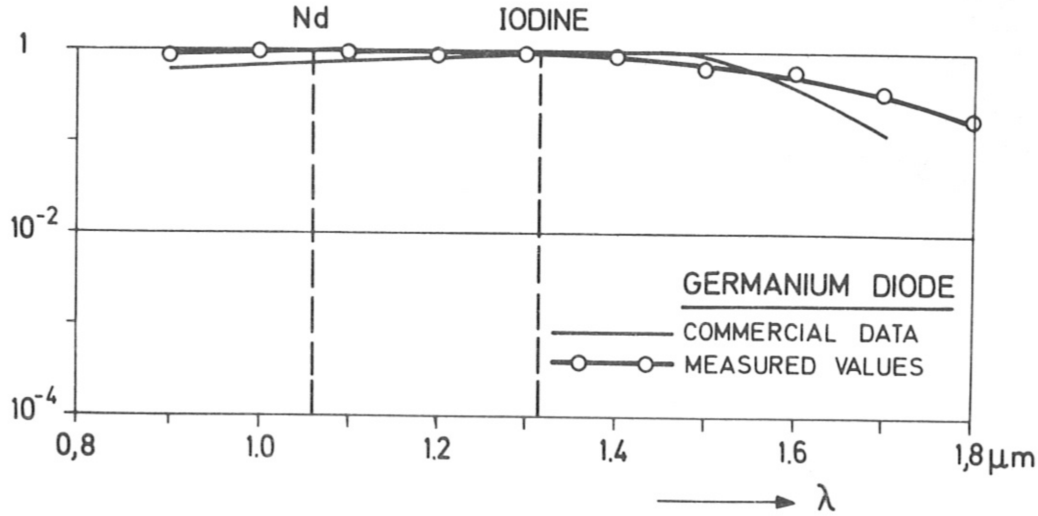

Fig.2 Spectral response of Ge-diode.

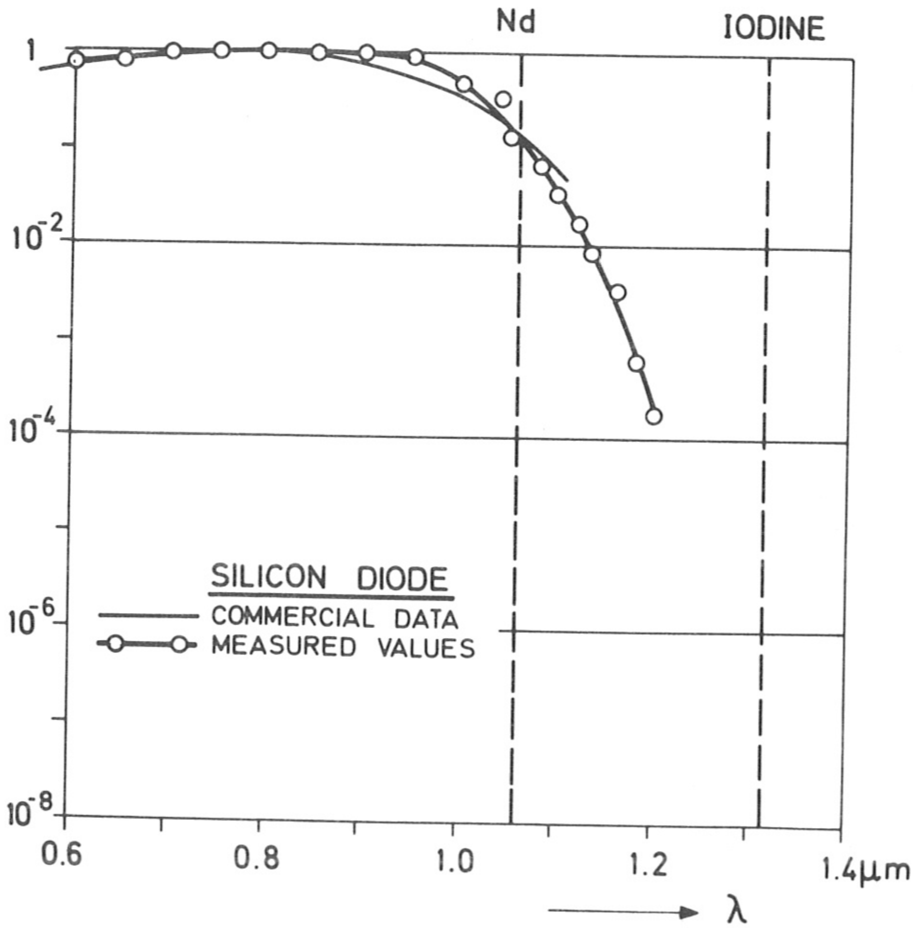

Fig.3 Spectral response of Si-diode.

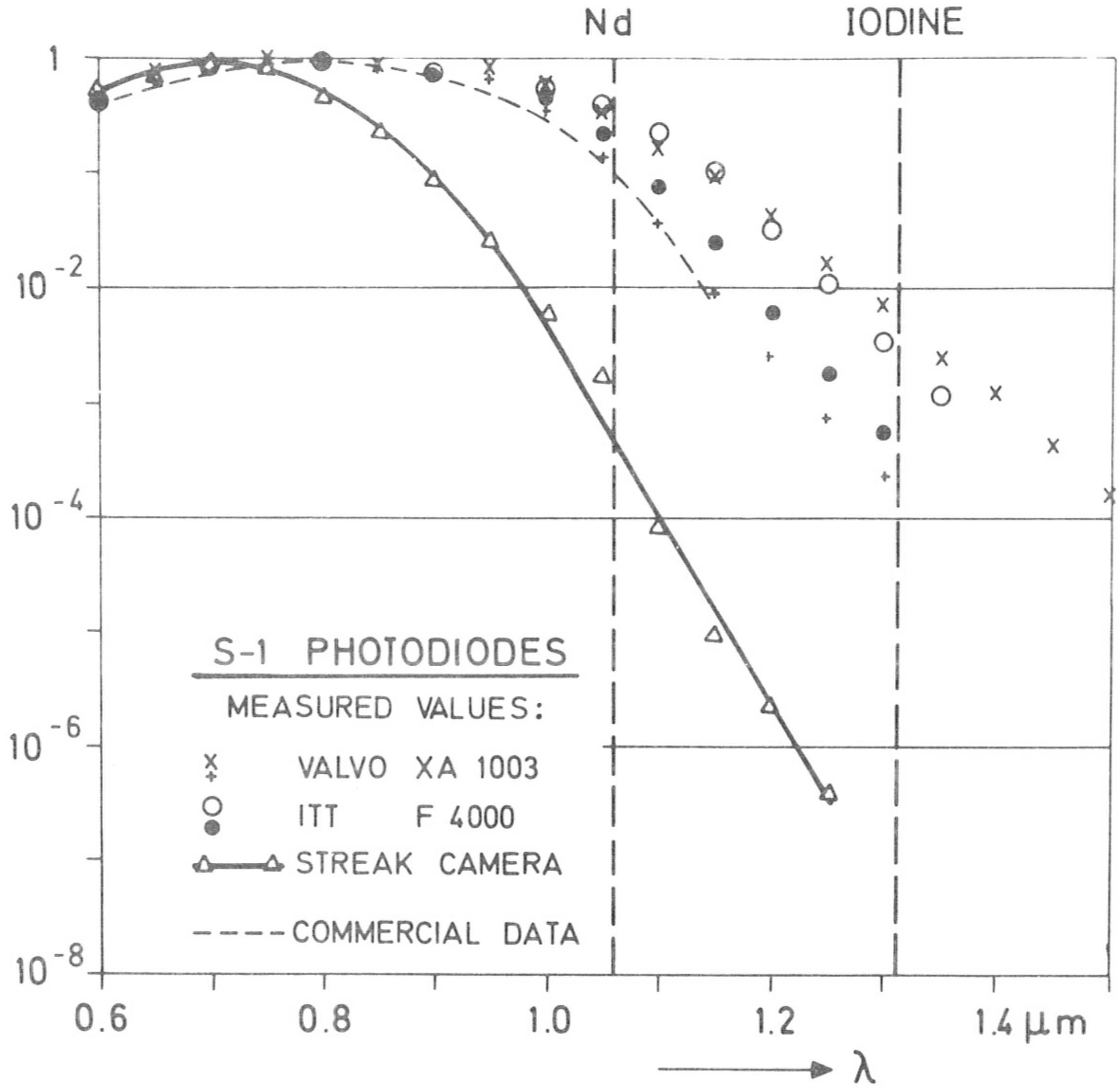

Fig.4 Spectral response of vacuum photo-diodes and of image converter camera.