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A. Dominjon,
R. Hermel,
J.C. Lacotte,
L. Massonnet,
M. Yvert,
Annecy-LAPP Team

Detection diodes, the second step

Generalities

This note follows the Virgo-note PJT94-014, in which we have summarized our first conclusions concerning the choice of the detection diodes. Our selection lead us to 3 candidates, the best being the OEM diode, we have ordered 10 of these. It turned out that none of the delivered detectors fulfilled the specifications, it seems that by luck. the specimen we had for tests was much better than the standard product. We have returned the diodes to the producer and turned ourselves to the Hamamatsu diode. In this note we give a summary of our last measurements concerning the high power behaviour, the temperature effect and the intrinsic noise of 3mm diameter InGaAs Hamamatsu photo-diodes. Finally we give some considerations concerning the quantum efficiency of these diodes.

High power behaviour

As discussed in the Virgo-note PJT94-014, we want to use the detection diodes in a regime far beyond their specifications. One of our desiderate is to work with an incident light power of 100mW on a diode biased with 10V. The total power dissipated in the diode is then about 1 watt and might lead to a destruction of the diode. Since it is usually admitted that a degradation of a photo diode manifests itself by a modification of the dark current versus bias voltage , we have measured the response of a "fresh" diode (8 minutes of exposition after delivery) and this same response after a total of 17 hours of exposition (I=100mA, Vb=10volts).

On fig1 we show this dark current response and we see that it is not significantly affected by this illumination. We plan to expand this test as soon as we have constructed a full detector prototype (10 diodes sharing a total input power of 1Watt, with a 10volts bias voltage)

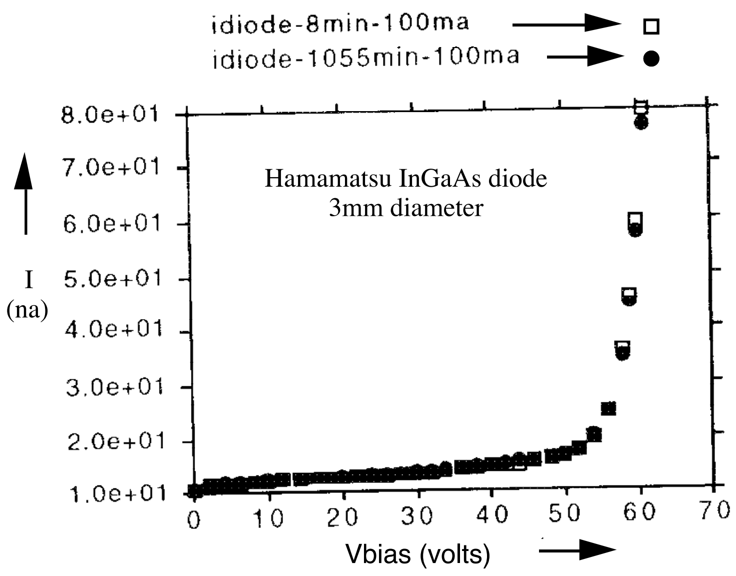

Fig 1

Temperature effects

A power of 1W dissipated in a diode will lead to a temperature increase which might induce some deterioration of its performances. In order to explore such an effect, we have heated a diode in an oven, measuring the dark current response before and after the baking.

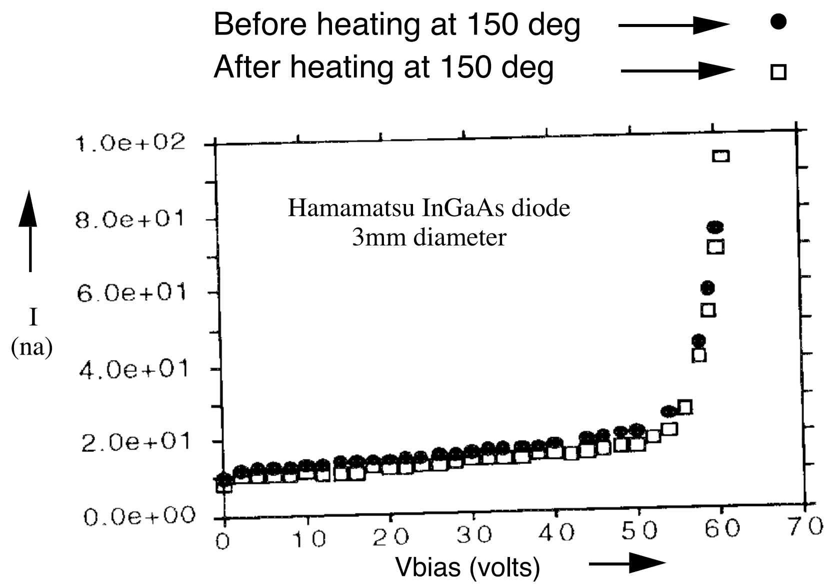

Fig 2

The small effect we see on fig2 (a lower dark current after baking), is purely experimental. It is due to a slight difference in temperature between the two measurements, no correction being applied for this effect. The conclusion is that no significant degradation of the diode is observed while baking it at 150 ^{0}C.

Taking advantage of the mounted experimental set-up, we have measured the dark current as a function of the diode temperature, while keeping the bias voltage fixed at 10 volts. The results are shown on fig3 where we have fitted the theoretical expectation[1]:

$$I_{dark} = I_\infty e^{-\frac{E_g}{kT}}$$

where E_g is the gap energy between the valence and conduction band , k is the Boltzman constant and T the temperature in Kelvin. Even if the measurement was not aimed at the evaluation of this parameter, we find a gap energy $E_g = 0.84$ eV which is quite satisfactory, when compared to the values of 0.82eV and 0.75eV found in the literature[2].

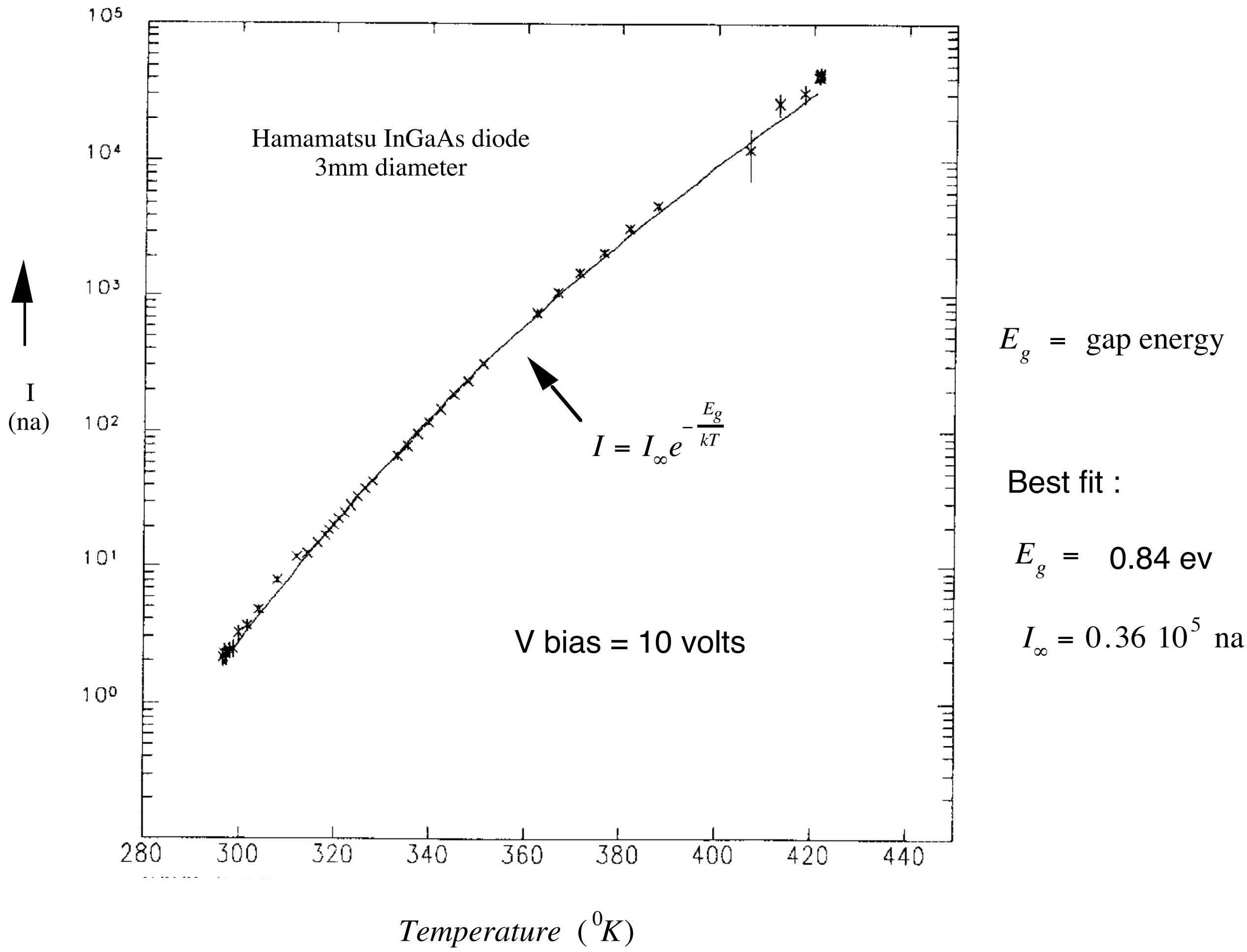

Fig 3

Intrinsic noise

Noise measurements have been performed illuminating the 3mm diameter Hamamatsu photo diode with a lamp, producing a DC current across it. The induced shot noise current is converted into voltage by a resistor, and measured using a low noise spectrum analyser at 10Mhz. The results are shown on fig4, the shot noise becomes dominant at a DC current of about 4mA, (remember that in VIRGO the photo diodes will be operated at DC current of about 50mA). The dependence of the shot noise versus DC current follows a square root law, as expected. No excess noise coming directly from the photo diode has been found in this measurement meaning that the intrinsic noise of this photo diode is low enough to meet out requirements.

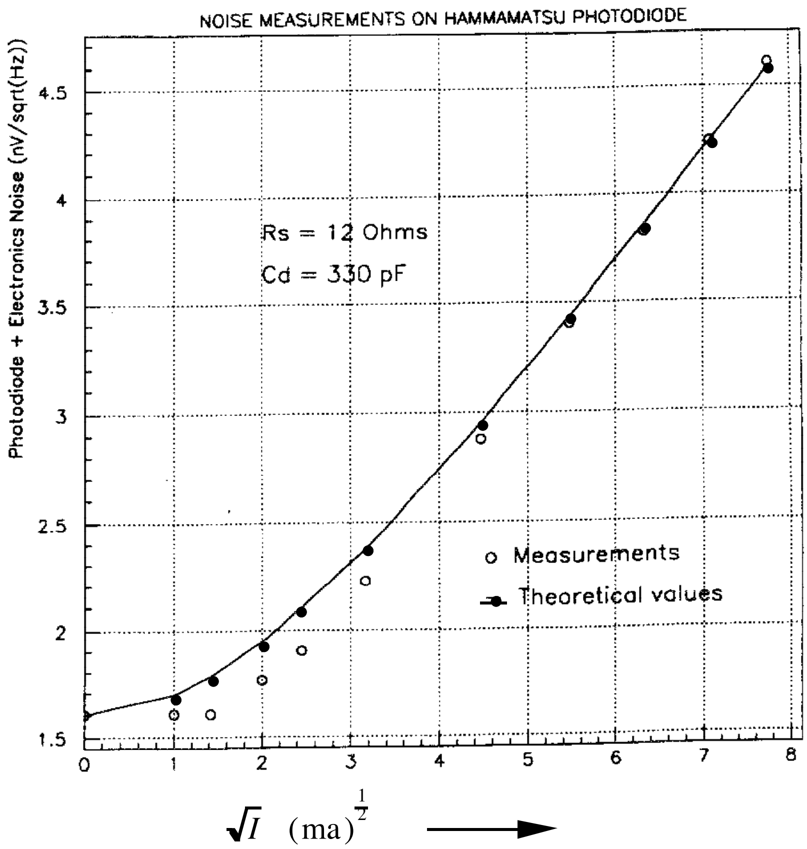

Fig 4

Considerations on the diodes quantum efficiency

The signal/noise ratio is proportional to $\sqrt{\eta}$ where η is the diode quantum efficiency. We have measured (a year ago) a coarse value of 90% quantum efficiency on a standard 1mm diameter InGaAs diode.It is possible to improve to 95% this quantum efficiency, and therefore to gain ≈2.6% in signal/noise by applying a suitable AR coating both on the two sides of the diode window and on the diode sensitive area itself[3]. Even if this treatment is quite expensive, we propose to apply it to the final diodes because it represents a significant gain in the overall interferometer efficiency[4].

Conclusions

Concerning the high power behaviour and the temperature effects, we have not detected any sign of weakness of these diodes under the severe test conditions to which they have been submitted. Further tests will be performed with larger statistics and during longer time, but from now on, we are quite optimistic concerning their use as final detectors. We find a gap energy in agreement with previous dedicated measurements, this result gives us a further confidence in the product.

The noise level found is quite satisfactory.

REFERENCES

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2) S.R. Forrest et al, Appl. Phys. Lett. 37(1980)322
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3)private communication from the Hamamatsu firm

4) remember that a 1% gain in signal/noise, due to diode quantum efficiency, is equivalent to a 1% gain in the VIRGO large cavities tube length, when looking in the frequency domain where we are dominated by the shot noise.