Double laser radiometry for study of detector linearity

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An experimental optical system of two laser sources and a silicon photodetector was built to test the double laser radiometry technique. The final goal is to achieve nonlinear region in silicon photodiodes and deactivate surface recombination centres in such a way that photocurrent produced by the photodiode will increase. We observe the present limit of performance of the measurement system at the level of 0.08%

INTRODUCTION

Linearity is a necessary property for high precision optical detector. The absolute responsivity of a photodiode should be stable over a certain period and constant over a certain range of irradiance [1,2]. Nonlinearity is a phenomenon well known in silicon photodiodes. Estimation of photodetector nonlinearity is essential for precise measurements. Activation of recombination centres is one reason of uncertainty in photodiodes. Recombination centres appearing are metallic impurities, most notably silver, which combine with boron in silicon to form latent recombination centres, and which only become active during the passage of several years. Moisture penetration through the package to the device over a long period of time is also a possible cause of observed changes in the quantum efficiency of boron-diffused devices over extended periods of time [2]. Moisture in conjunction with boron is suspected to cause recombination centres near the oxide-silicon interface, and moisture has been reported to neutralize the ionized boron acceptors by hydrogen injection creating a surface region depleted of ionized boron. Deactivation of recombination centres could increase the reliability of measurements. Characterising the supralinear region where recombination centres are deactivated will allow to increase the accuracy of measurements.

In this work, we built a custom developed optical setup to test the idea of double laser radiometry and check the availability of deactivation of surface recombination centers in silicon detectors.

DOUBLE LASER RADIOMETRY SETUP

The idea of the double laser radiometry technique is the usage of two laser sources simultaneously (Fig. 1): near infrared laser as a source of measured signal and blue laser for filling up recombination centres at the photodiode surface, because of small penetration depth. An optical chopper modulates near infrared light. The light spots from the two lasers coincide on the photodiode active area. The blue beam may deactivate recombination centres, so this technique can increase photodiode responsivity. The set-up consists of two CW diode laser sources with wavelengths of 405 nm and 785 nm. Near infrared light is attenuated with neutral density (ND) filter, polarizer and then modulated by optical chopper. Blue light is attenuated with ND filter in a filter wheel. Two beams are brought together with a dichroic

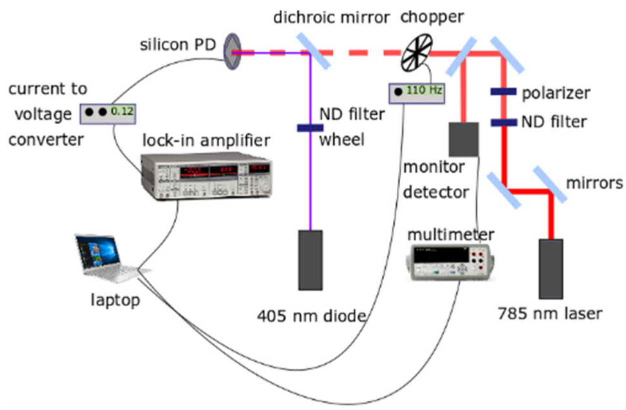

Figure 1. Double laser radiometry optical system.

mirror so light spots from the lasers overlap on the photodiode active area. We used a monitor detector to check near-infrared laser's stability and a lock-in amplifier to measure the signal from the near-infrared laser. As only 785 nm light is modulated with the optical chopper, the lock-in amplifier measures only the near-infrared signal and the blue light signal is neglected. To detect changes in the weak signal we used a custom-built current-to-voltage converter (CVC) with an amplification of 10^3 and Stanford Research S830 lock-in amplifier. As the detector we chose Hamamatsu S2281 silicon photodiode and a custom-made predictable quantum efficient detector (PQED). The PQED consists of two induced junction photodiodes that are mounted in a wedged trap configuration for the reduction of reflectance losses [3].

The final goal is to study the supralinear region in PQED photodiodes and deactivate surface recombination centres in a such way that the overall signal will increase when using the double laser technique.

MEASUREMENTS AND DATA PROCESSING

During the measurement process, the automatic filter wheel of blue light changed its position between two states: one with opaque ND filter with high absorbance and another one without any filter. In one position, the set-up records ten measurement points and then the filter wheel switches to another position. The monitor detector allowed correcting the near-infrared laser signal instability. Figure 2 shows the relative difference in lock-in amplifier signal with and without blue light.

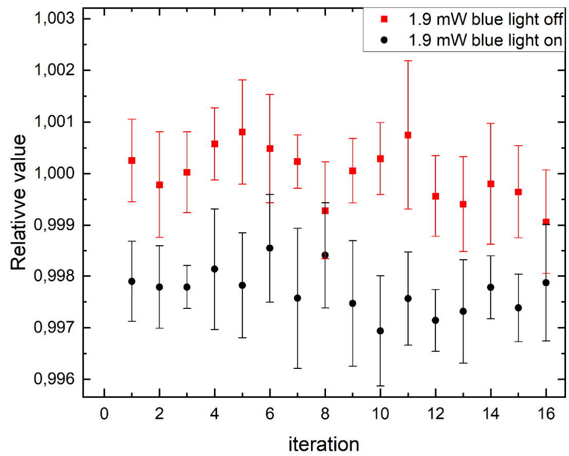

Figure 2. Normalised signal from the lock-in amplifier at 465 μW modulated power of the 785 nm laser and 1.9 mW DC power of the 405 nm laser

We used different power levels of the near-infrared laser to study the tested photodiode (Fig. 3). During data processing all points from one ”cycle” were averaged and compared with each other. Such

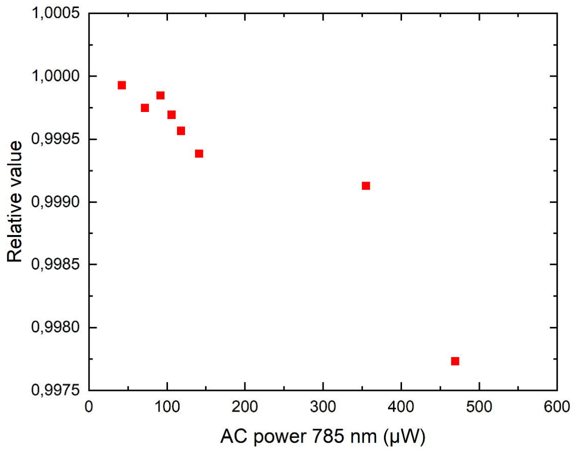

Figure 3. Ratio of near-infrared laser signals from the lock-in amplifier with 1.9 mW blue light off and blue light on.

measurement allows checking the dependence on laser power, irradiation time, and other conditions. The limit of performance of the measurement is about 0.08% as concluded from data points (Fig. 3). We seem to start achieving saturation region in the photodiode with the 465 μW signal.

We have also noticed that irradiation of the borders of the photosensitive area with the two lasers leads to reaching supralinear region at various power levels that coincides with results achieved earlier by Tanabe and Kenichi [4]. The next step is to conduct measurements with PQEDs to study possibility of deactivation of surface recombination centres.

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