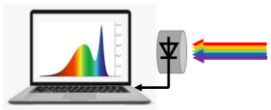

Miniature optical spectrometer based on optoelectronic chromatic dispersion in a PN-type germanium photodiode

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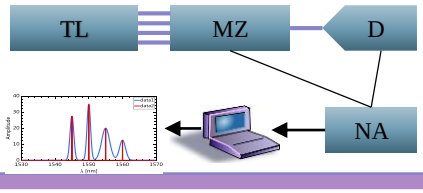
Abstract

Optoelectronic chromatic dispersion (OED) has been shown to be a significant source of chromatic dispersion in photodiodes [1] and has been utilized for high-resolution spectral sensing [2-4].

We present results of spectral resolution using a Ge PN photodiode in the C-band. The resolution obtained with the Rayleigh criteria was 20 pm. We also present results of spectrum reconstruction over a wide spectral range with resolution of 0.8 nm.

First step
Database construction

In the first stage, the photodiode is illuminated with modulated light in the C-band which consists of one or more spectral peaks and varying power levels, in order to characterize the RF response, as per a defined protocol. The goal of this 'learning stage' is to build a 2D grid database consisting of 9 spectral resolution points in the C-band with a spectral resolution of 5nm per point, and 4 amplitude levels. Subsequently, this database is used to reconstruct an arbitrary spectrum that illuminates the photodiode.



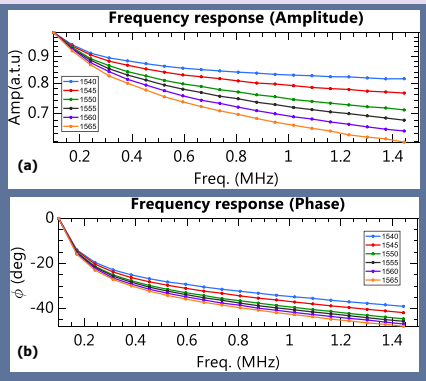


Fig. 1 Frequency response of Germanium photodiode **(a)** amplitude response **(b)** phase response

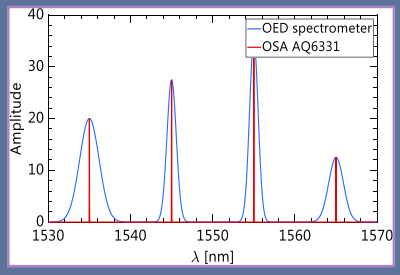


Fig. 2 Spectrum reconstruction. Red: measured spectrum with a high-resolution commercial spectrometer; Blue: reconstructed spectrum

Second step
Spectral reconstruction

First, the least square root algorithm was tested. This method gave excellent reconstruction accuracy for up to two spectral peaks. A second algorithm, based on the minimum distance method, gave 97% accuracy when matching 4 peaks. Using this method, we demonstrate spectral reconstruction with 1.6 nm resolution and amplitude standard deviation of 2%. Furthermore, we are developing advanced AI-based algorithms which will lead to further improvements in the learning efficiency and reconstruction accuracy.

Conclusion

OED-based spectroscopy in photodiodes is a new technique for chip-size inexpensive optical spectroscopy. Expanding this method to silicon and other materials will lead to chip-size embedded spectrometers in the visible and IR.

References

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