New voltage control technique for Mach-Zehnder modulators

Vervoort S(1,2), Wolff M(1)*

(1) Heinrich Blasius Institute for Physical Technologies, Hamburg University of Applied Sciences, Hamburg, Germany
(2) School of Engineering and Computing, University of the West of Scotland, Paisley, UK

*Corresponding author's email: marcus.wolff@haw-hamburg.de

Introduction – For amplitude-modulated Photoacoustic Spectroscopy (PAS) the optical power of the laser must be periodically varied to excite the sample in a way that an acoustic signal develops. The modulation of a radiation source that cannot be directly modulated, such as an Optical Parametric Oscillator (OPO), can be achieved electro-optically by means of a Pockels Cell (PC) and a Mach-Zehnder Interferometer [1,2].

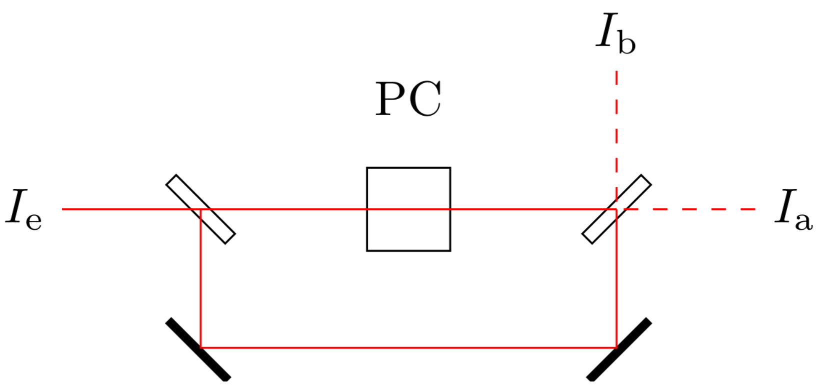

Fig. 1. Mach-Zehnder Intensity Modulator including PC, entrance beam I_e and both outlet beams I_a and I_b.

The basic setup of such a Mach-Zehnder Intensity Modulator (MZM) is shown in Fig. 1. At the first beam splitter (left), the continuous-wave laser is divided equally into two partial waves. Subsequently, one beam is phase-modulated by the PC. When the two beams reunite behind the second beam splitter, the interference leads to intensity-modulated outputs [3].

Method – Since the photoacoustic detection module with its resonator acts as a bandpass filter and cuts off signals outside the bandpass, a high stability of the modulation frequency is required. However, MZMs often suffer from phase drifts that cause operating point fluctuations and signal instabilities. By controlling the bias voltage of the PC it is possible to maintain its quadrature operating point [4]. From the ratio between the average output power and the first-order harmonic signal the required bias correction can be calculated. An approach using a Fast Fourier Transform to control the PC bias voltage achieved stable operation (phase shift: ±0.08°) over three hours [5].

Since the optical wavelength influences the required half-wave voltage of the PC, measurements over a wider spectral range, such as with an OPO, require a control-loop for both, the half-wave and the bias voltage to maintain its optimum operation point. We developed a new concept of a control-loop based on Discrete Fourier Transform (DFT) that allows control of both voltages simultaneously.

Results – A mathematical model of the MZM allows mimicking the influences of the bias voltage and the half-wave voltage on the intensity modulation. Fig. 2 shows two different states in which the MZM does not operate optimally. The upper two diagrams show the case that the bias voltage does not compensate for the phase drift. The lower two diagrams demonstrate what happens if the modulation voltage does not properly match the half-wave voltage of the PC. In both cases harmonics occur. However, the two phenomena can be distinguished from each other: only the half-wave voltage influences the odd harmonics while both voltages excite the even harmonics. The new DFT based control-loop evaluates the DC component, the fundamental and the first two harmonics.

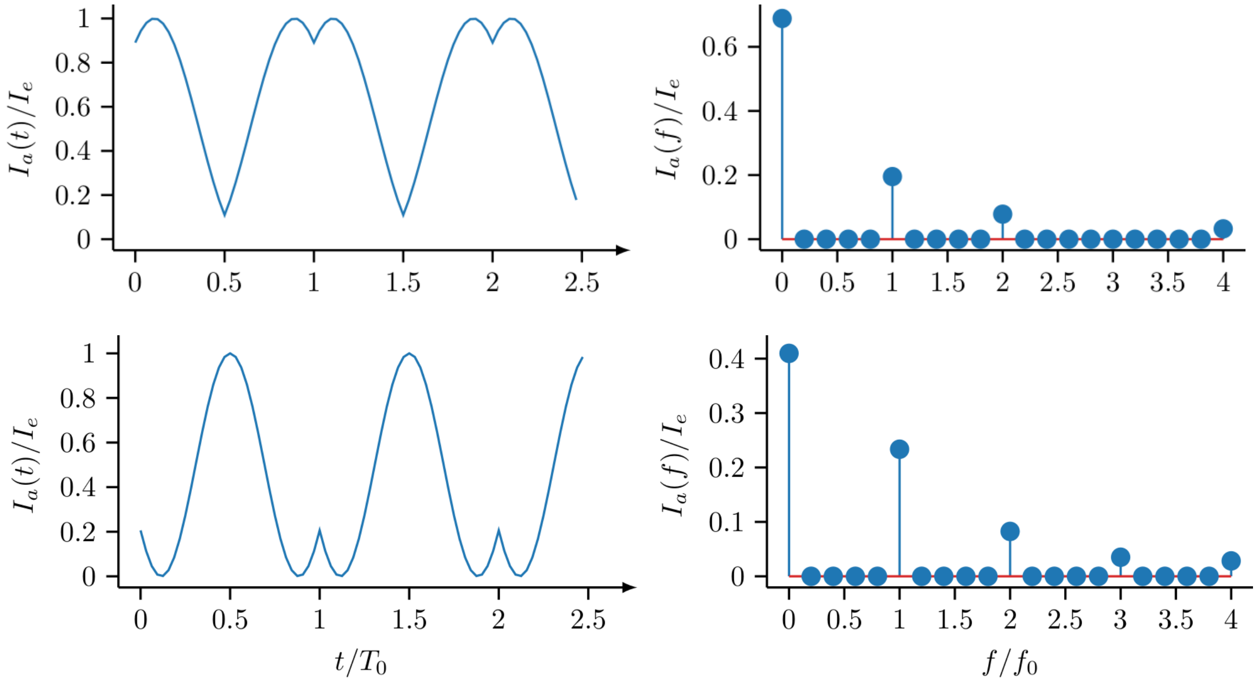

Fig. 2. Intensity ratio between output I_a and entrance I_e in time domain (left) and frequency domain (right). Mismatch of bias voltage (top), mismatch of half-wave voltage (bottom) (modulation frequency; f_0; period: T_0).

References

[1] L. Zehnder, Ein neuer Interferenzrefraktor, Zeitschrift Für Instrumentenkunde 11 (1891) 275–285.

[2] L. Mach, Ueber einen interferenzrefraktor, Zeitschrift Für Instrumentenkunde 12 (1892) 89.

[3] H. Bruhns, Y. Saalberg, M. Wolff, Photoacoustic Hydrocarbon Spectroscopy Using a Mach-Zehnder Modulated cw OPO, Sensors & Transducers 188 (2015) 40.

[4] Y. Li, Y. Zhang, Y. Huang, Any Bias Point Control Technique for Mach–Zehnder Modulator, IEEE Photonics Technology Letters 25 (2013) 2412–2415. https://doi.org/10.1109/LPT.2013.2285184.

[5] J. Svarny, S. Chladek, Model-Based Bias Controller for a Mach-Zehnder Intensity Modulator, Journal of Lightwave Technology 40 (2022) 720–727. https://doi.org/10.1109/JLT.2021.3122460.