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Highly sensitive measurement of the optical Kerr effect in air

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The optical Kerr effect offers unique access to measuring high electric field strengths without any necessity for introducing additional materials into the sample volume. While the Kerr effect induces a readily measurable birefringence effect in materials like nitrobenzene, the resulting effect in air amounts to $B \approx 3\text{x}10^{-19}$ m/V ^{2}, which is about 7 orders of magnitude weaker than in nitrobenzene. Previous attempts to accurately measure this quantity therefore relied on ~100 m long path lengths or elevated pressures and required voltages of several ten kilovolt to generate a measurable effect. Here we experimentally demonstrate the electro-optic Kerr effect in a 8 cm long intracavity capacitor at atmospheric pressure. This capacitor is placed inside a mode-locked laser and is resonantly driven in an LC circuit at 17.5 kHz and at an amplitude of a few kV. The Kerr effect inside the capacitor assembly induces differences between group and phase velocity of the light. Even though only a very small path length is affected from this modulation, the laser pulses pass the capacitor assembly 80 million times per second. Within a single modulation cycle, this gives rise to an effective propagation length of 300m inside the capacitor. Nevertheless, this effect is even smaller than the induced birefringence but can be very sensitively measured via the carrier-envelope phase. To this end, we frequency-double the laser light and bring it to interference with the fundamental light on a photo diode. The radio frequency spectrum of this signal shows a beat signal with a faint frequency modulation, which can then be used to estimate the strength of the intracavity Kerr effect, see Fig. 1.

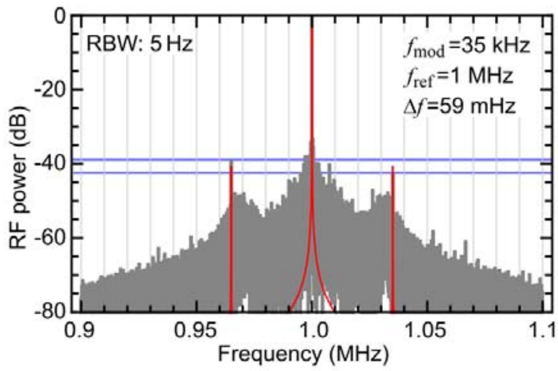

Figure 1. Recorded radio frequency spectrum of the beat signal between fundamental and second harmonic. The beat note shows to faint FM sidebands at the doubled capacitor drive frequency.

Our proof-of-principle measurement offers surprising new access to contactless (and even probe-less) high voltage measurements, just using atmospheric air as the medium. It converts the measurement of a field strength into measurement of the frequency modulation index of a radio frequency signal. Much higher sensitivities appear to be achievable when exploiting the electro-optic Kerr effect in the fiber of a fiber laser. This may open a new avenue for contactless high voltage measurements.

References

1. Tianli Feng, Pascal Rustige, Nils Raabe, and Günter Steinmeyer, "Intracavity measurement of the electro-optic Kerr effect via carrier-envelope phase demodulation," Opt. Lett. **41**, 5158-5161 (2016)