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High-speed Sample and Hold using Low Temperature Grown GaAs MSM Switches for Photonic A/D Conversion

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Abstract: We demonstrate 20 giga-sample/s (GSa/s) Nyquist operation capability of a sample and hold circuit using optically triggered metal-semiconductor-metal (MSM) switches made of low temperature (LT) grown GaAs. Good linearity and flat frequency response are achieved for the sample and hold process, indicating potential for much higher sampling rates.

OCIS codes: (999.9999) Photonic A/D Conversion

With the ever-growing demand for bandwidth, the need for high-speed A/D converters operating at GSa/s sampling rates has emerged in the areas of radar and microwave communications. As a solution, the idea of combining the low jitter and high speed advantages of photonics with electrical A/D converters has spawned a number of photonic A/D conversion systems [1-3]. In our system, we utilize a sample and hold scheme with LT grown GaAs MSM switches. The short recombination lifetime and high mobility of LT GaAs allow high-speed operation with good sensitivity [4]. Optically triggered by a short-pulse laser, the switches would be attached to a transmission line and would sample the input electrical signal onto a hold capacitor.

Previously, we demonstrated a sample and hold circuit achieving a sampling gate width of less than 2 ps and 5.7 effective number of bits under dc input conditions [5]. In addition, we incorporated a differential configuration to eliminate feedthrough noise on the hold capacitor.

In this work, we demonstrate a sample and hold circuit accurately sampling a 2 GHz and a 10 GHz input, yielding Nyquist operation up to 20 GSa/s. To our knowledge, this represents the fastest continuous-time sampling capability of any optically assisted sample and hold process.

The sample and hold structure was made by attaching the MSM switch and hold capacitor in series across the signal and ground lines of a transmission line. The entire structure was made by depositing titanium/gold contact metal for both MSM and transmission line patterns on a LT GaAs layer grown on a GaAs substrate.

Time-resolved electro-optic sampling was used to measure the voltage across the hold capacitor. A schematic of the experimental setup is shown in Fig. 1. The mode-locked laser provides an 80 MHz repetition rate optical pulse train. Frequency multipliers were used to generate the 2 GHz or 10 GHz electrical sinusoid (~3 Volts peak-to-peak) phase-locked to the pulse train. Electrical mixers allow windowing of the input signal. The hold capacitance value is ~15 fF with a pump pulse energy of ~0.2 nJ.

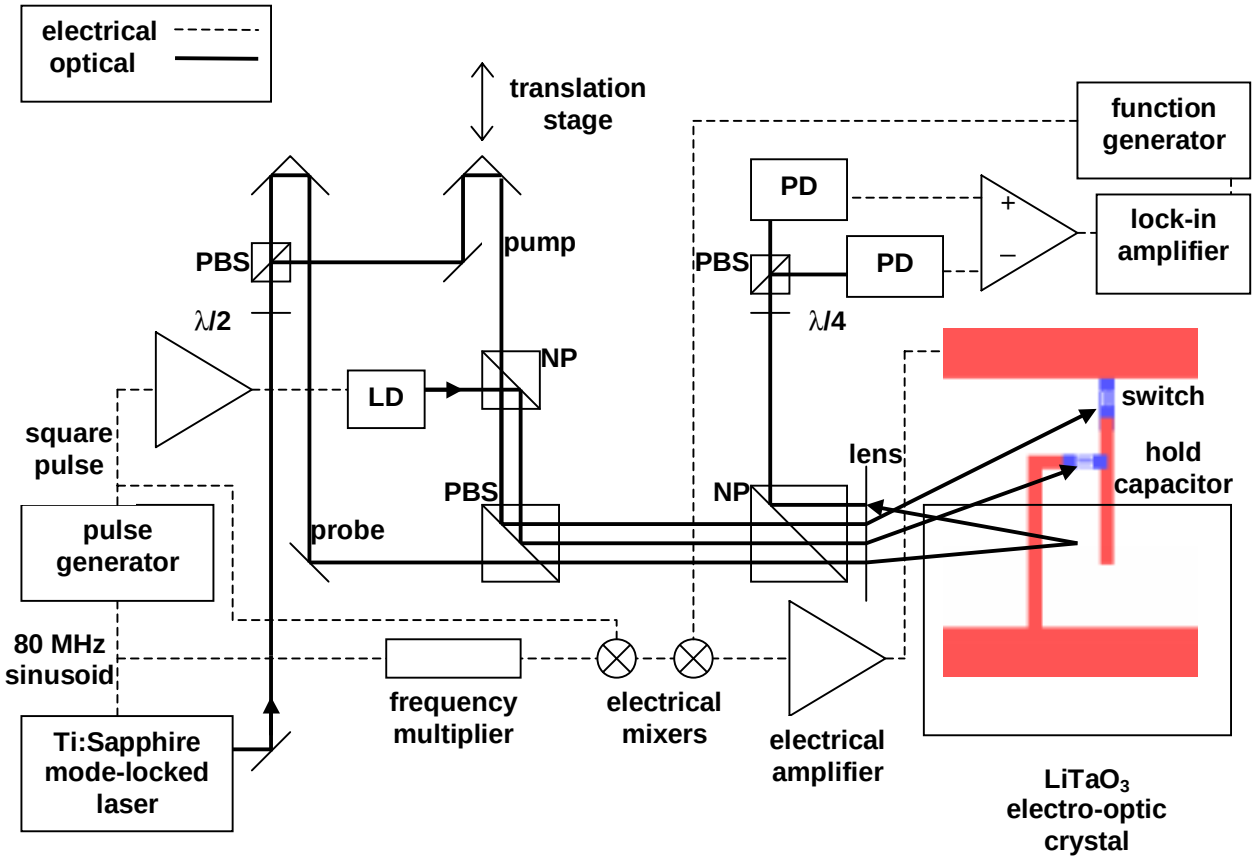
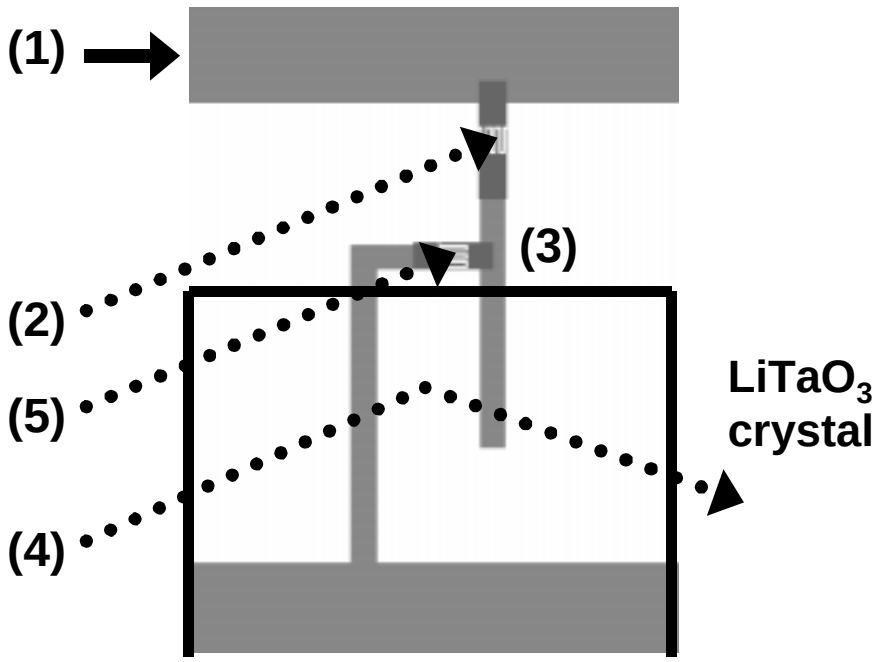


Fig. 1. Schematic of experimental setup. Solid lines represent optical beams, dotted lines represent electrical connections. Pump light closes MSM switch. Probe light detects voltage across hold capacitor and is reflected back into differential configuration photodetectors. Laser diode is directly modulated, producing a nanosecond-order pulse which hits hold capacitor MSM and resets the held voltage to ground. Frequency multiplier and electrical mixers are used to create windowed RF input signal. PD – photodetector. PBS – polarizing beam splitter. NP – non-polarizing beam splitter. LD – laser diode.

Figure 2 shows a timing diagram for the measurement. The pump pulse closes the MSM switch, sampling the input signal onto the hold capacitor. The probe pulse then samples the voltage across the hold capacitor via the electro-optic crystal. A reset pulse placed during the zero period of the input signal discharges the hold capacitor by triggering the hold capacitor MSM, returning the circuit to initial conditions. By varying the pump pulse phase relative to all other inputs, different points of the input signal are sampled.


(1)
(2)
(3)
(5)
(4)
LiTaO3
crystal

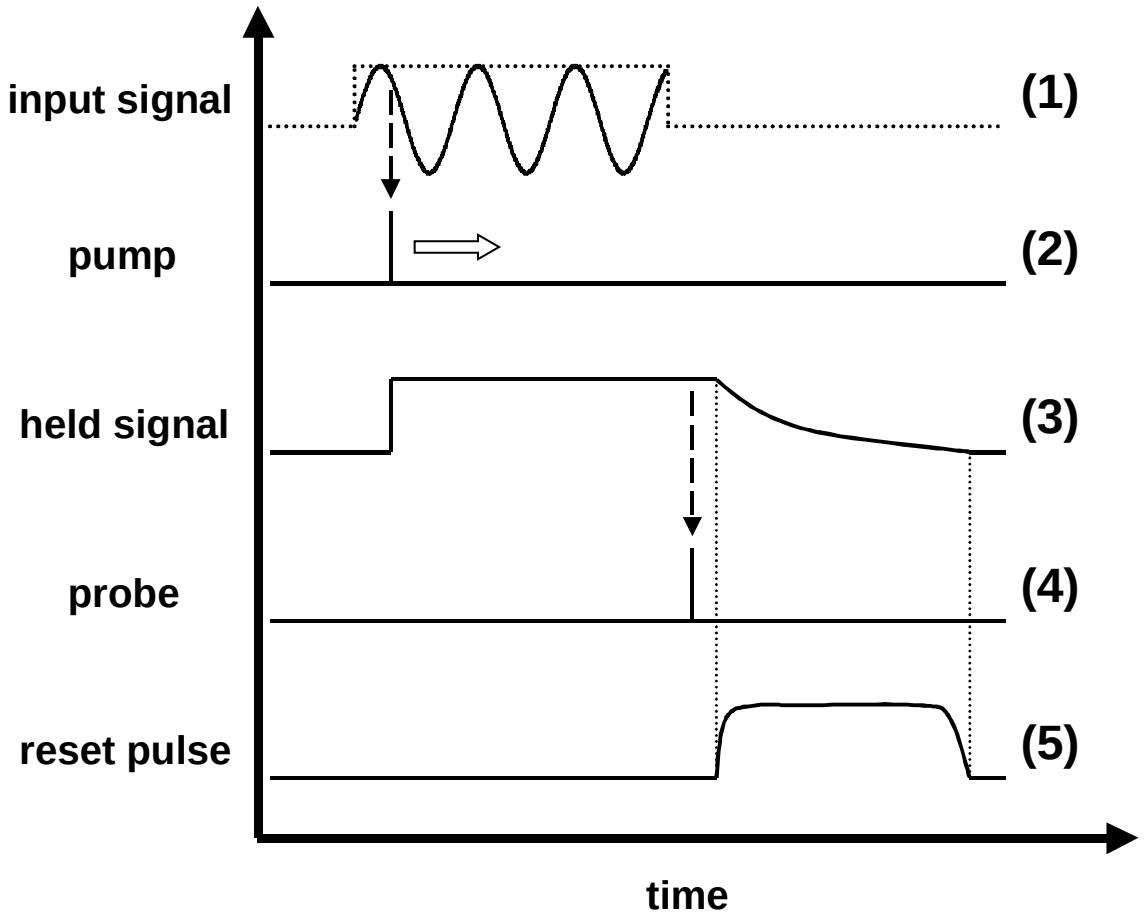

input signal
(1)
pump
(2)
held signal
(3)
probe
(4)
reset pulse
(5)
time

Fig. 2. Timing diagram for time-resolved electro-optic sampling measurement. Location of appropriate signal is designated by matching number of corresponding trace. All signals are phase-locked, with relative phase of the pump being changed. For simplicity, held signal does not indicate feedthrough noise.

Results of the measurement are shown in Fig. 3. The top trace is for the 2 GHz input, the bottom trace for the 10 GHz input. Dots indicate sampled points with solid lines showing pure sinusoids accurately matching data, confirming the linearity of the device for the input voltage range used. Furthermore, the amplitudes of the two electro-optic signals are nearly identical. This extremely flat frequency response up to 10 GHz indicates a ps order sampling gate width and potential for much higher sampling rates.

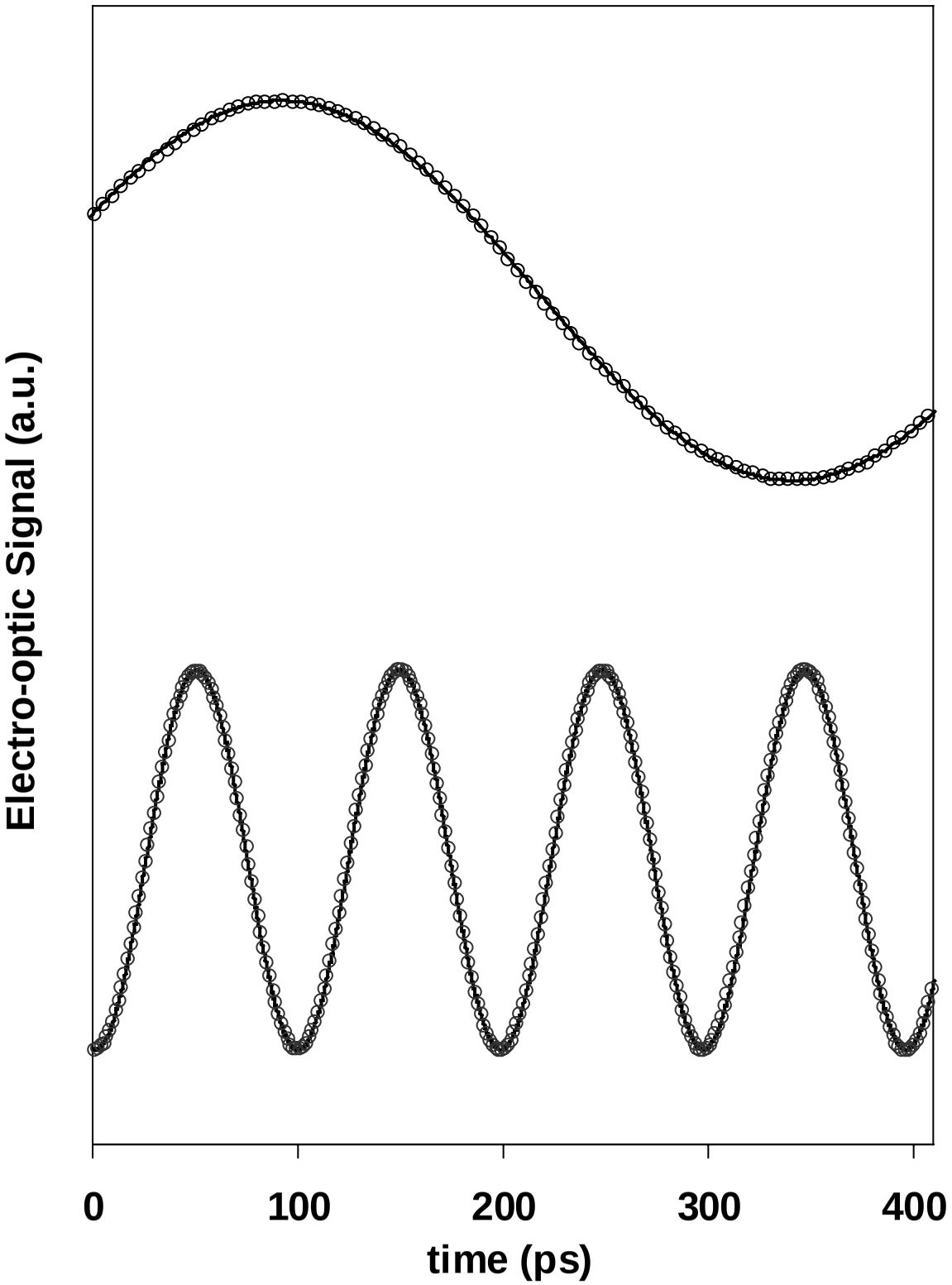


Fig. 3. Held signal for 2 GHz (top) and 10 GHz (bottom) input signals. Dots indicate sampled points with solid lines showing pure sinusoids fit to data. Pump pulse energy was ~0.2 nJ for both measurements.

In conclusion, we have demonstrated a high-speed sample and hold circuit capable of Nyquist operation up to 20 GSa/s. Good linearity and a flat frequency response are achieved, indicating potential device performance at speeds far beyond the 20 GSa/s limit set by input source availability.

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