Conf-910595--1

BNL-45416

PERFORMANCE CHARACTERISITICS OF MACH-ZEHNDER MODULATORS FOR TRANSFER OF DETECTOR SIGNALS BY OPTICAL FIBERS*

T. Tsang, V. Radeka, T. Srinivasan-Rao

Brookhaven National Laboratory, Upton, NY 11973

and

W. J. Willis

Columbia University, New York, NY

November 1990

***This research was supported by the U. S. Department of Energy: Contract No. DE-AC02-76CH00016.**

BNL--45416

DE91 008439

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T. Tsang, V. Radeka, T. Srinivasan-Rao, and W. J. Willis*

Brookhaven National Laboratory, Upton, NY 11973

*BNL and Columbia University, New York, NY 10027

ABSTRACT

The results of the preliminary measurements of the optical power requirement, linearity, dynamic range, and noise characteristics of a Mach-Zehnder electro-optical modulator will be presented. The modulator system will be used to minimize the local electronics on a large scale particle detector.

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The readout of $\sim 10^6$ electronic particle detectors with high degree of parallelism in signal transfer and processing is recognized as a major challenge. In this study, we utilize an integrated electrooptic modulator and fibers for such a readout system. The optical system comprises of a diode-pumped Nd:YAG laser, a Mach-Zehnder (MZ) interferometric modulator with x-cut y propagating $Ti:LiNbO_3$ waveguides, low noise InGaAs photodiodes, and fast shaping amplifiers.

When a charge is injected on one of the electrode of the MZ interferometer, the optical length of one arm changes the relative phase at the end of the interferometer. The output laser power will vary as the square of the cosine of the total phase shift.[1-2] The MZ modulator has a -3 dB intensity modulation point close to the zero bias point, its transfer characteristic is shown in Figure 1. The fringe intensity has an extinction ratio of 26 dB with a V_π voltage of 2.68 V. For a 1% maximum deviation from a tangent through the -3 dB point, the maximum signal $\frac{V_\pi}{4\pi}$ is ~ 200 mV in our case. If the noise is limited by the photon statistics, the dynamic range with respect to the noise is $0.25\sqrt{\frac{t_m n_o}{a_F}}$, where n_o is the photoelectron rate, t_m is the integration time, and a_F is a filter parameter.[3] Using a light intensity at the detector of 1 mW, n_o is 6.7×10^{15} sec^{-1}. With $t_m = 35$ ns and $a_F \simeq 1.9$ for our case, the expected dynamic range is $\sim 3 \times 10^3$. By measuring the voltage height of the modulator-receiver responses shown in Figure 2 with different input modulation voltages, the linearity curve is generated in Figure 3. The linearity of the modulated signal is quite good, and the dynamic range is slightly $\geq 3 \times 10^3$.

The noise sources considered in this experiment includes the photodiode, the receiver system, dielectric noise from the modulator, laser noise and photon fluctations. The low noise photodiode contributes a noise of ≤ 200 rms e^-, which is much less than the photon noise that we would anticipate. Based on a calibration run of the receiver-detector system (Figure 2), it has $\leq 3 \times 10^3$ rms e^- (~ 0.5 fC). Our estimate of the dielectric noise due to the thermal fluctuations in the dielectric constituting the modulator[3] is ≤ 500 rms e^-. The photon noise at the receiver is given by $\sqrt{a_F n_o t_m}$. For 1.2 mW light input to the receiving photodiode, the average currrent is ~ 1.02 mA, which corresponds to a shot noise of 2.10×10^4 e^-. With a step signal of 10 mV input to the modulator, we measured a signal of 1.28×10^6 e^- and a measured noise of 2.25×10^4 rms e^- at the receiver-detector. Therefore, the photon noise is clearly dominant over other noise sources and is $\sim 7\%$ higher than the shot-noise-limit at the detection bandwidth.

To obtain a faster shaping time and better sensitivity, a BNL made 2 ns risetime pulser and a hybrid circuit fast preamp and shaper with 3 ns peaking (integration) time were employed in the receiver-detector system. Details of this work and the results of the noise measurements using a travelling wave MZ modulator will be presented.

References

1. S. K. Korotky and R. C. Alferness, *Optical Fiber Telecommunication II*, New York, Academic Press, p.421 (1988).
2. C. K. Bulmer and W. K. Burns, J. of Lightwave Technology, **LT-2**, p.512 (1988).
3. V. Radeka, Ann. Rev. Nucl. Part. Sci. **38**, pp. 217-277, 1988.

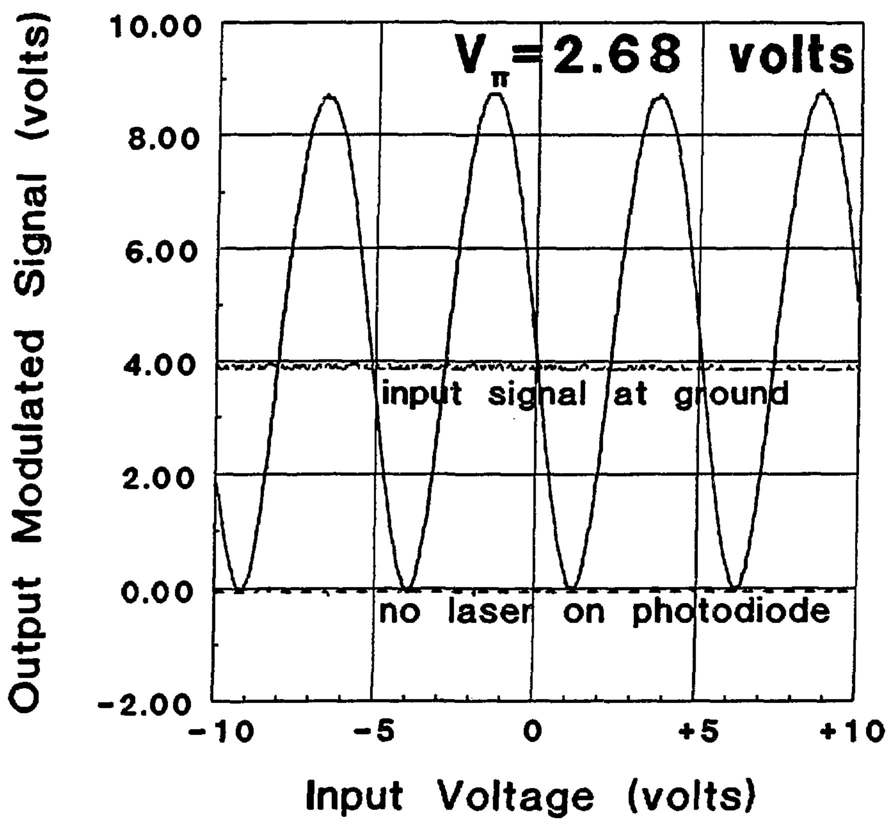

Fig. 1 Transfer characteristics of the MZ modulator.

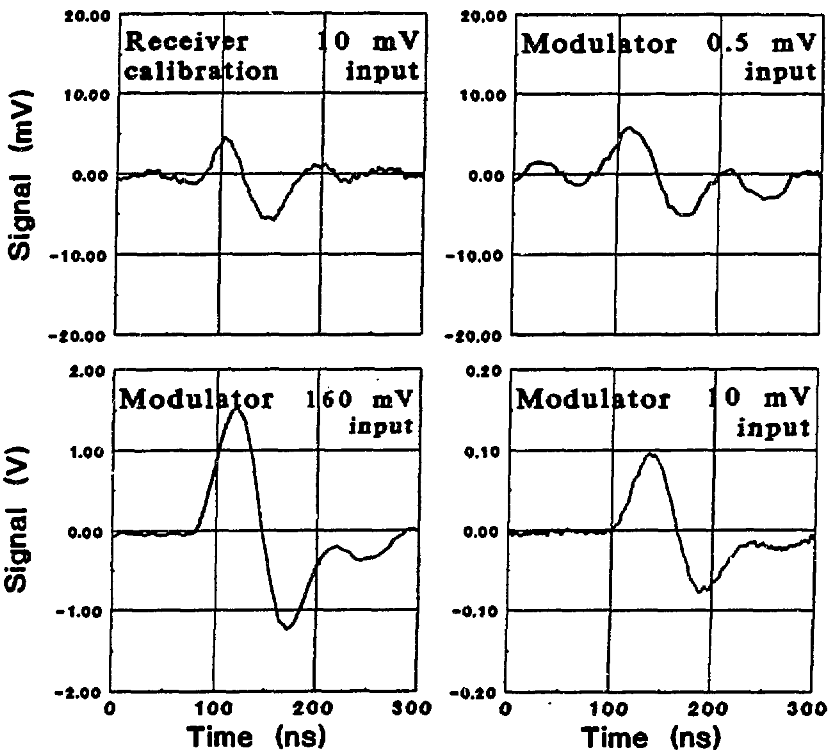

Fig. 2 Modulator-receiver response for various input modulation voltages at shaping time of $\tau_i = \tau_d = 20$ ns. Input equivalent noise is 0.1 mV.

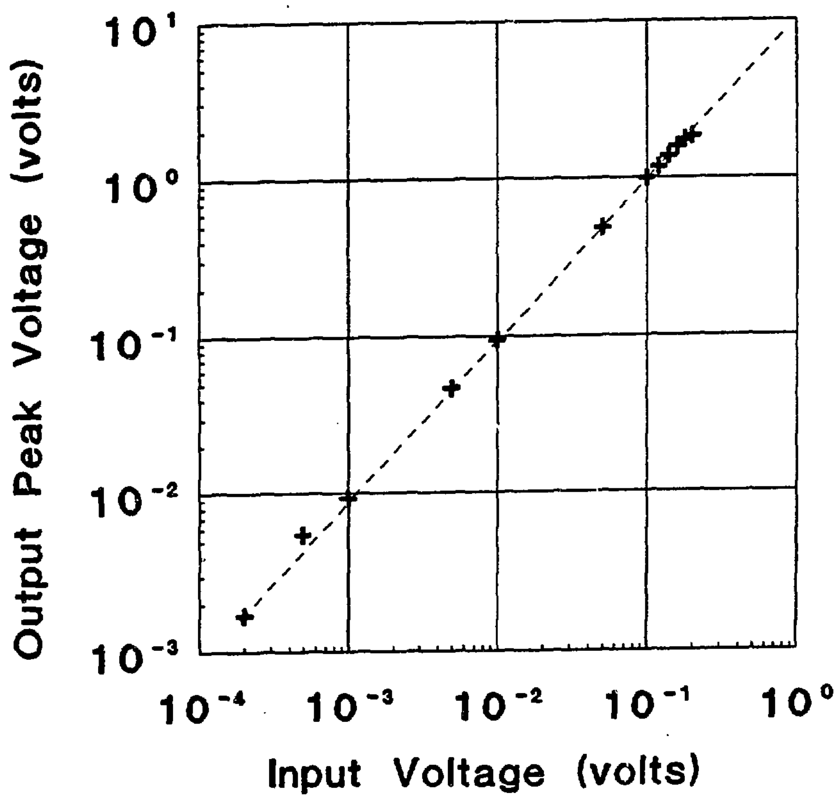

Fig. 3 Linearity of the MZ modulator.