The prospects of Free Electron Analog to digital Technology

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Free electron analog to digital conversion is accomplished by deflecting an electron beam bunch transversally by the voltage to be sampled, and then quantizing the deflected angle in an array of electron detectors. Miniaturization of the whole system, but specially the deflection plates, leads to an improved performance [1].

A system restricted by the fundamental limit of diffraction could achieve a sampling rate of 1 THz with 8 bits resolution; the source requirements would be brightness of 2e13 A/str/cm2 at 5kV, and source jitter of 1 fs. A more practical system using an negative electron affinity photocathode electron source with brightness of 1e7 A/str/cm2 at 5kV will allow the system to sample 4bits at 750 GHz or 6 bits at 450 GHz (fig 1).

The system we studied consists of a mode-locked laser and photocathode based source , a miniaturized traveling wave deflector; and Metal-Semiconductor-Metal electron detectors. Beyond the use of a low jitter sampling train, the advantage of the system is the direct-encoding spatial quantization nature of the electron beam deflection, that provides a digital output without the need of a comparator. This eliminates the ambiguity limitation of performance [2], but causes the system to be limited by the bunch effective time length.

Previous experiments demonstrated the deflection plates [3] and the MSM detectors [4] working into the GHz regime; recently we obtained ADC functionality using a thermionic electron source blanked and deflected with 2 pairs of identical plates. Limited by the deflection RF source we obtained 5 bits at 50 MHz sampling.

The flexibility of an electron beam system translates in the possibility of using multiple beams deflected by a single plate, which lowers the requirements on the readout electronics and detectors; and the possibility of reconfigurable ADCs that tradeoff speed for resolution by changing the acceleration voltage. However the biggest challenge of such a system is the feeding of broadband electrical signals in and out of the necessary evacuated system through coaxial feedthroughs; this shows its advantage as a narrowband system such as one for Radar applications where the feeding is done via waveguide feedthroughs.

[1] R.F.W. Pease, K. Ioakeimidi, R. Aldana, R. Leheny, *Photoelectronic ADC using miniature electron optics: basic design considerations*, Journal of Vacuum Science & Technology B21, pp 2826-2829 (2003)..

[2] R.H. Walden, *Analog to Digital converter survey and analysis*, IEEE J. Select. Areas Commun., vol.17, pp.539-549, Apr.1999

[3] R. Aldana, R.F.W. Pease, *Miniature traveling wave deflection for electron beam analog to digital conversion*. Microelectronics Engineering; vol. 84, I. 5-8, p. 806-809 (May 2007)

[4] R. Aldana, R.F.W. Pease, *Metal-Semiconductor-Metal electron detectors*. Journal of Vacuum Science & Technology. B 25, 2077 (2007)

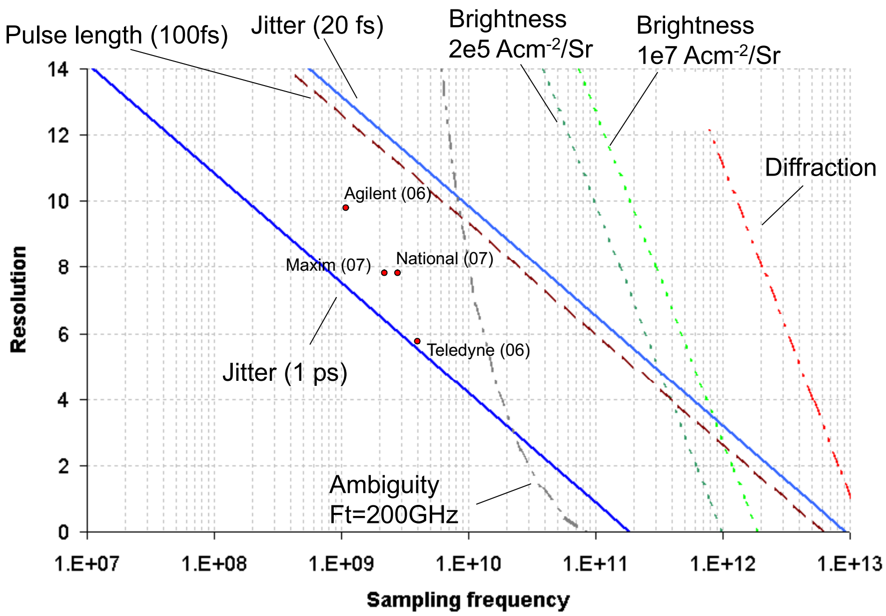

Figure 1. Performance limits for a ADC.

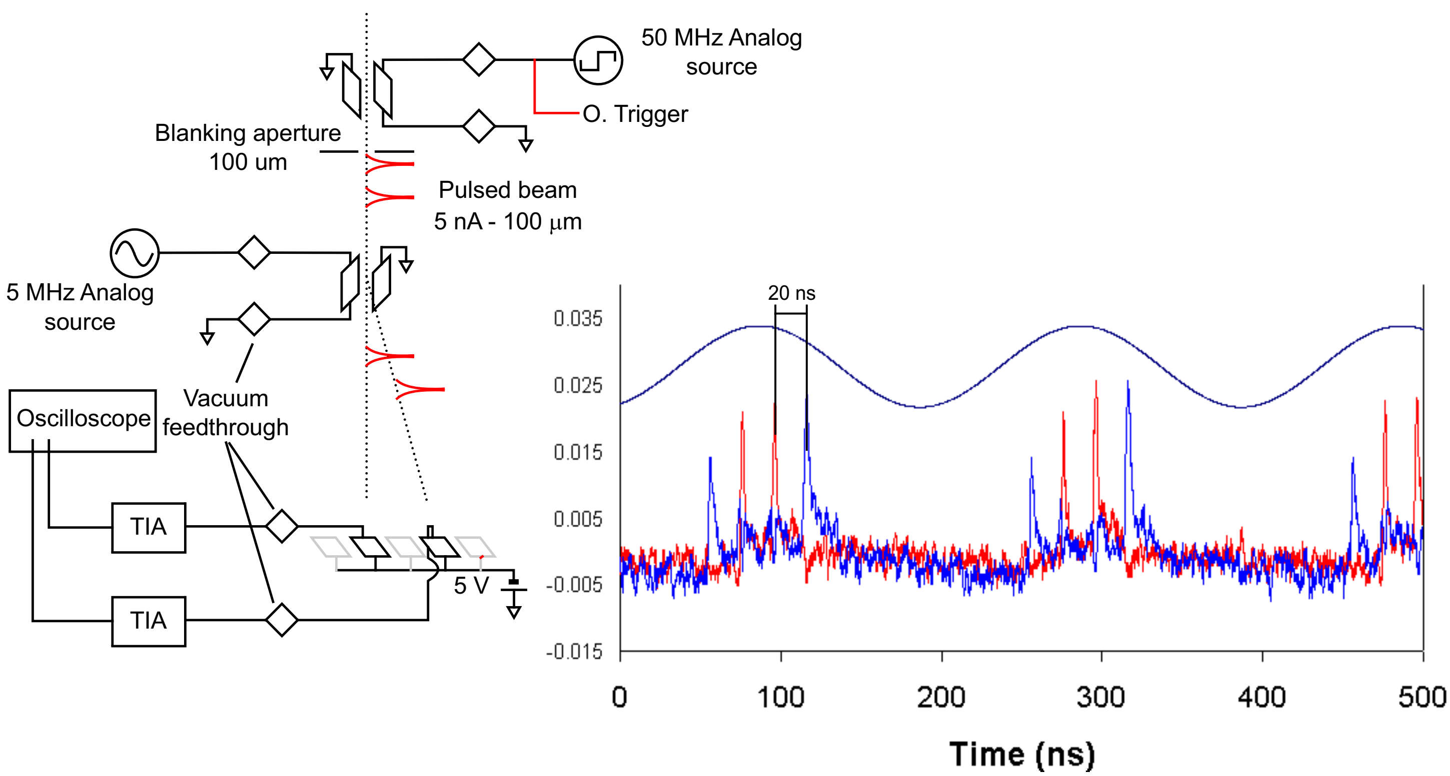

Figure 2. ADC system description and experimental results: output from 2 100 µm detectors separated by 200 µm; top is analog sampled signal.