An Ultra-high-Speed Waveform Digitizer Prototype for High-Intensity Laser Plasma Diagnostics

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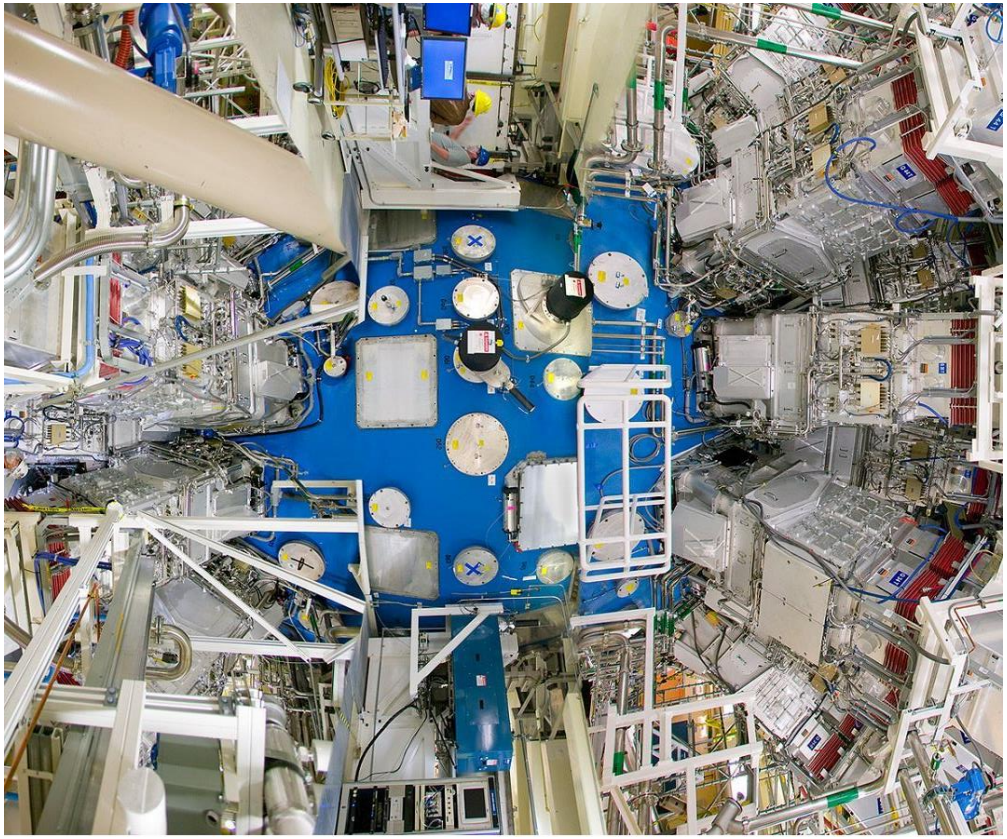
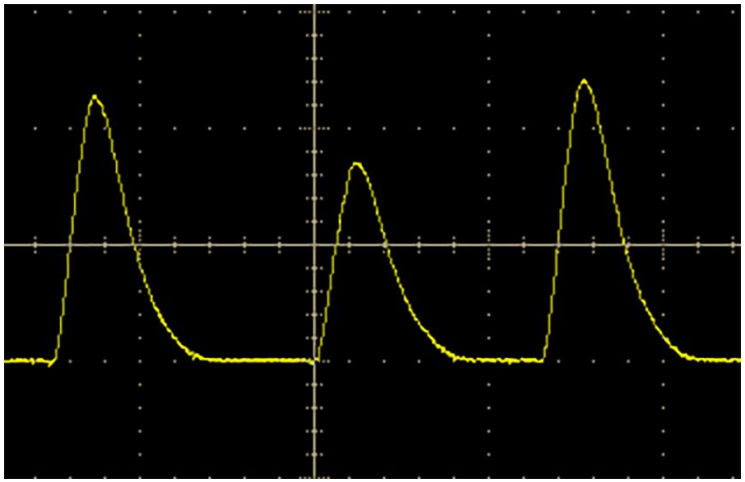
Introduction



- High-intensity lasers are used to produce plasma
- A series of detectors are installed around the target chamber to conduct plasma diagnostics.

Introduction



Waveform digitization:

- Time measurement
- Amplitude measurement (Energy)
- Waveform Analysis (Particle identification)

With the development of the experimental technology, the number and performance of detectors are increasing

There is a growing demand for waveform digitizers

Introduction

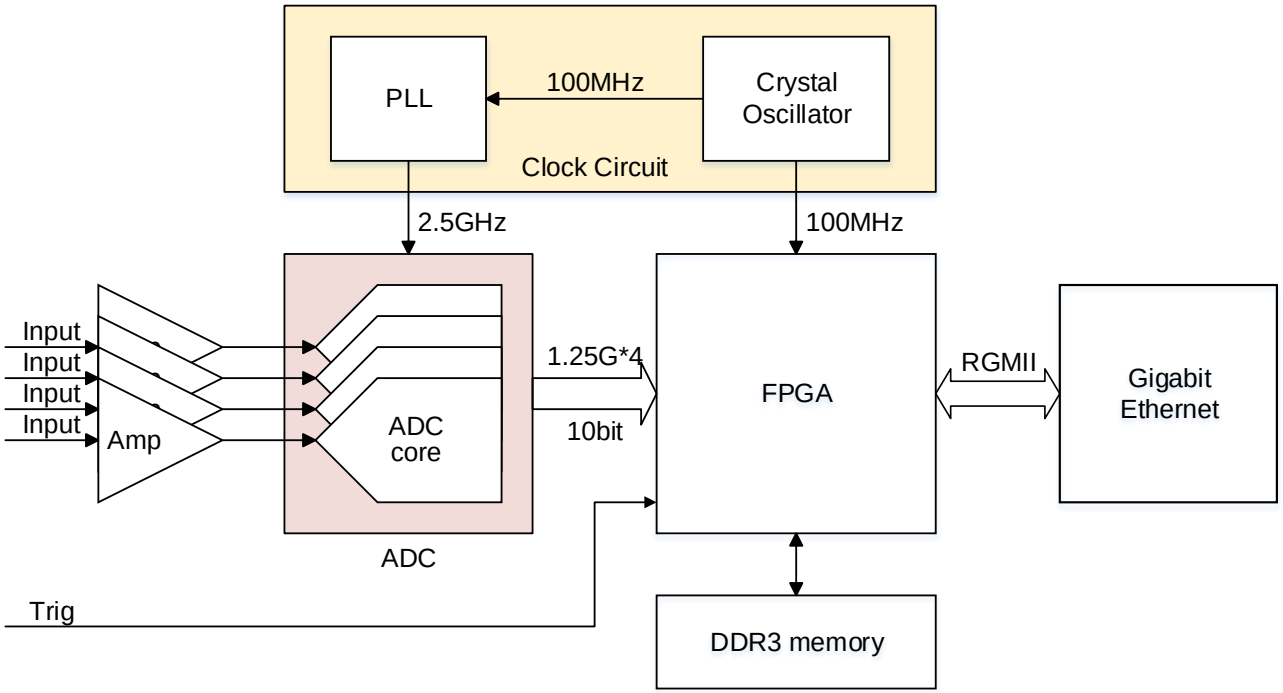
Universal waveform digitizer :

1. High speed, bandwidth and resolution
   meet needs of various measurements

2. Enough speed interface between digitizer and computer
   upload data within the experimental intervals

3. Small volume and power consumption
   be installed conveniently

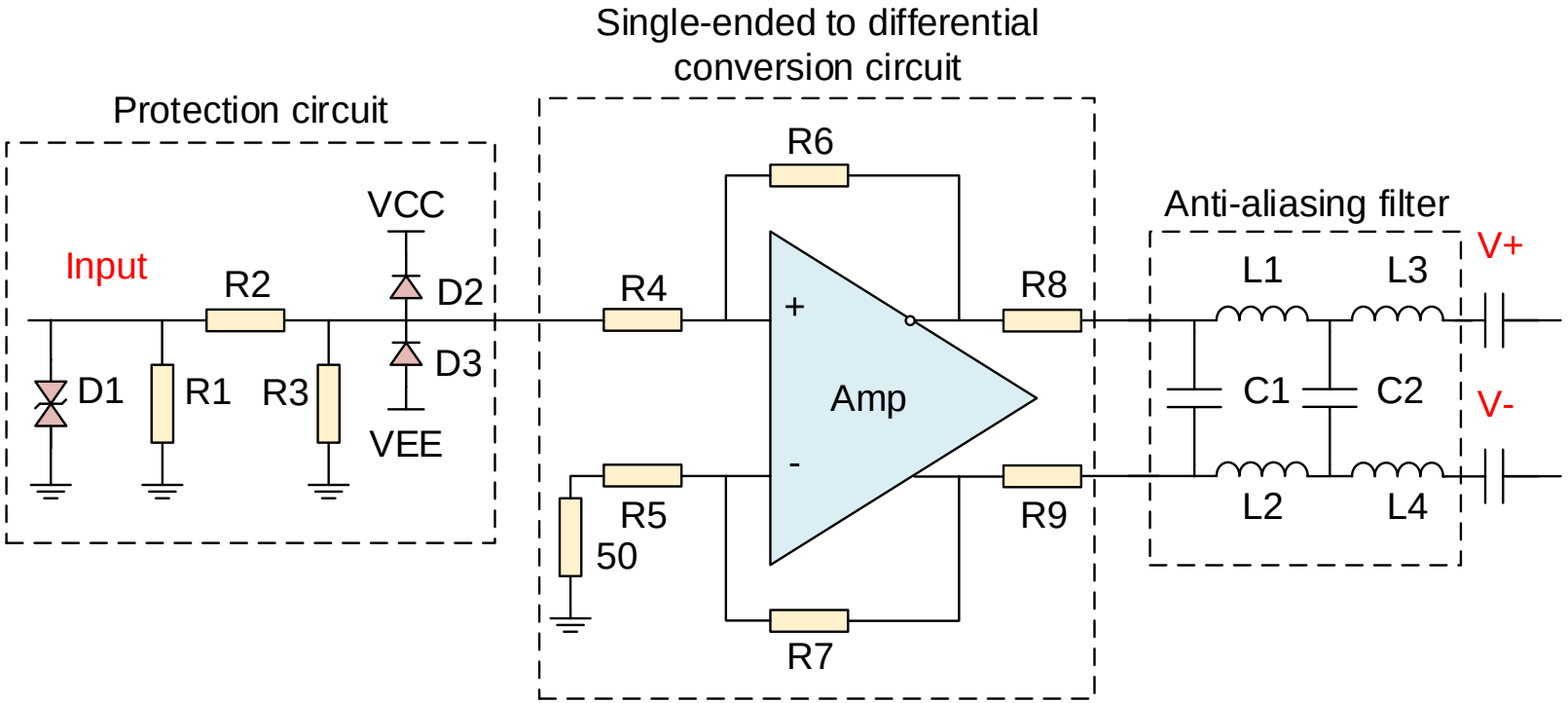
Implementation



- 5Gsps(1.25*4)
- 10bits
- 4GB DDR3

An ultra-high speed waveform digitizer prototype

Analog Conditioning Circuit



TVS diode: ESD protection

π-type resistor network: termination and amplitude attenuation

D2/3: large signal protection

Fully differential amplifier: single-ended detector signal to differential level

Anti-aliasing filter: filter out the high frequency noise

Clock Circuit

Jitter of sampling clock has a significant effect on ENOB

Ignoring all other noises:

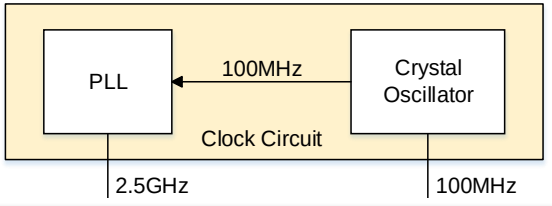
$$SNR = -20\log(2\pi f_{in} t_{jitter\_total})$$

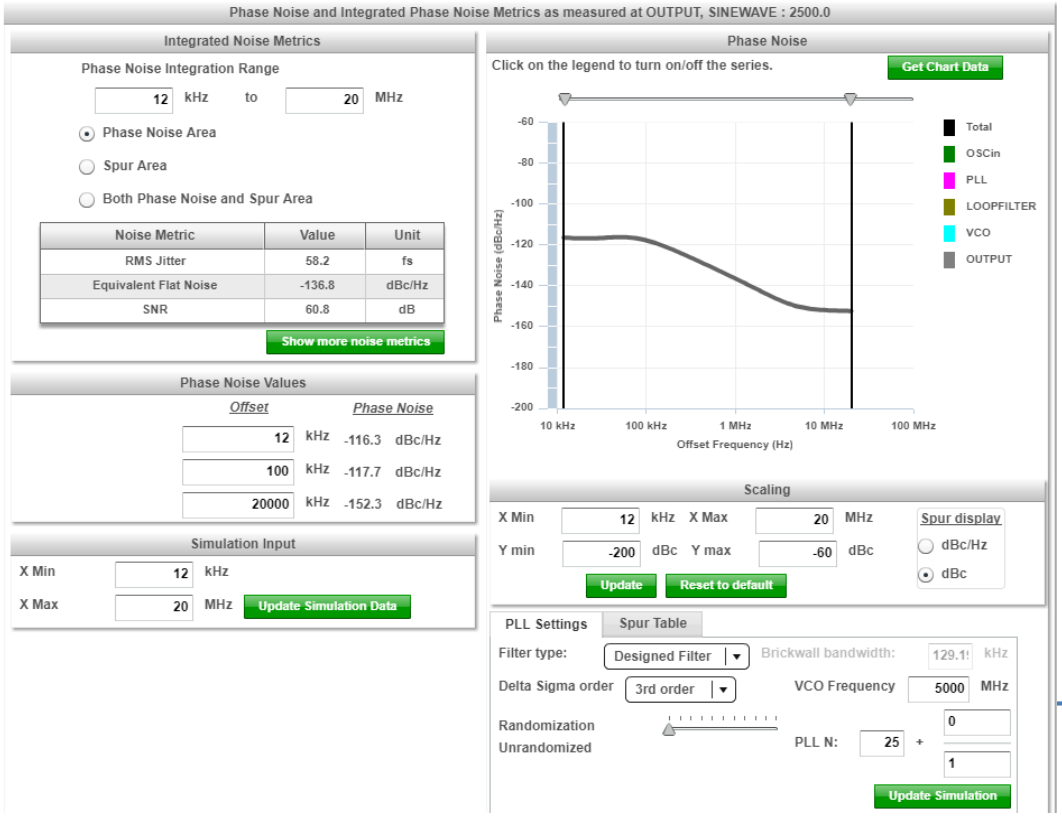
$$ENOB = (SNR-1.76)/6.02$$

$$t_{jitter\_total}^2 = t_{jitter\_clk}^2 + t_{jitter\_ape}^2$$

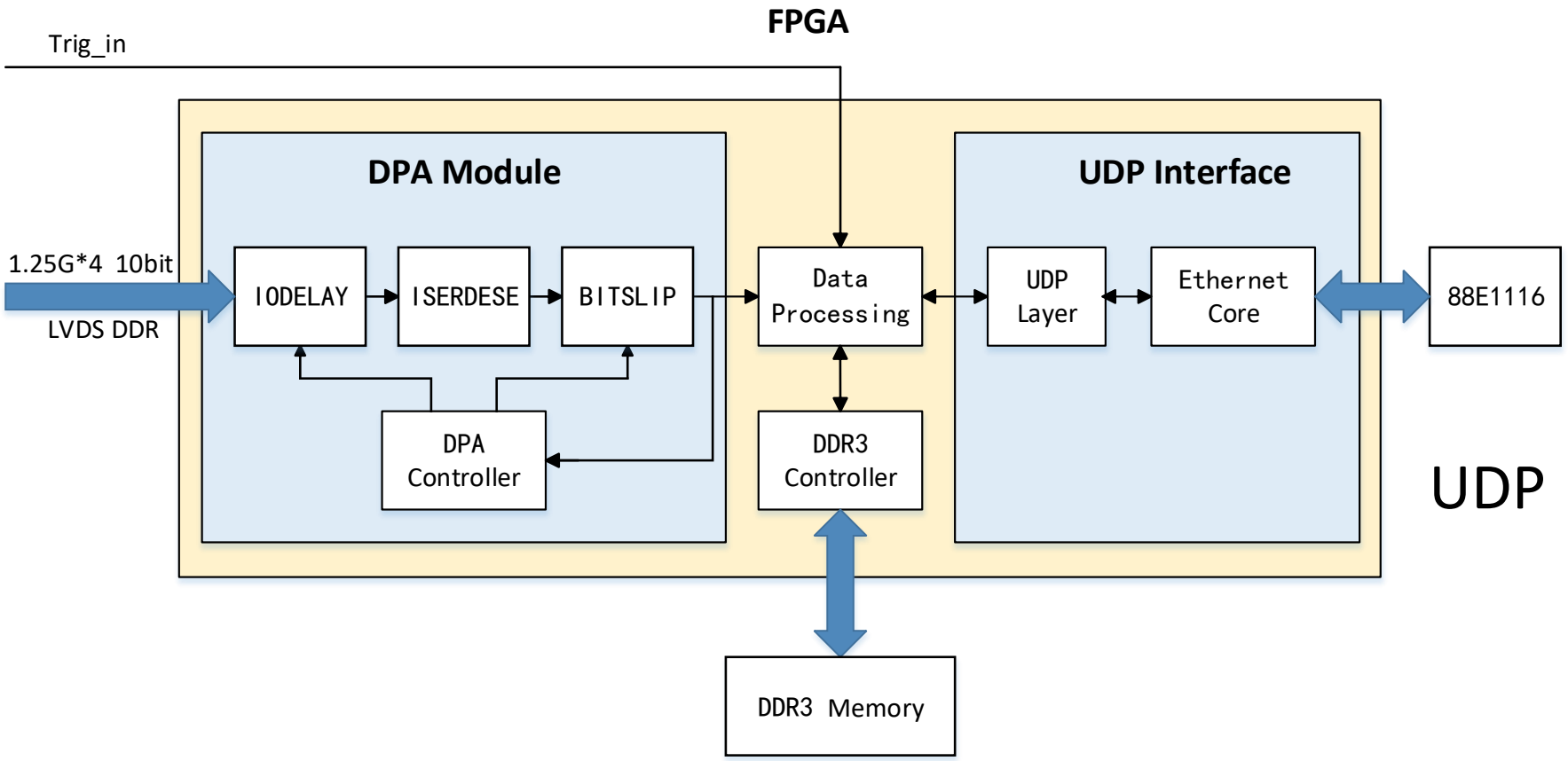
Clock Circuit

$t_{jitter\_clk} < 60fs$





Signal Flow in FPGA



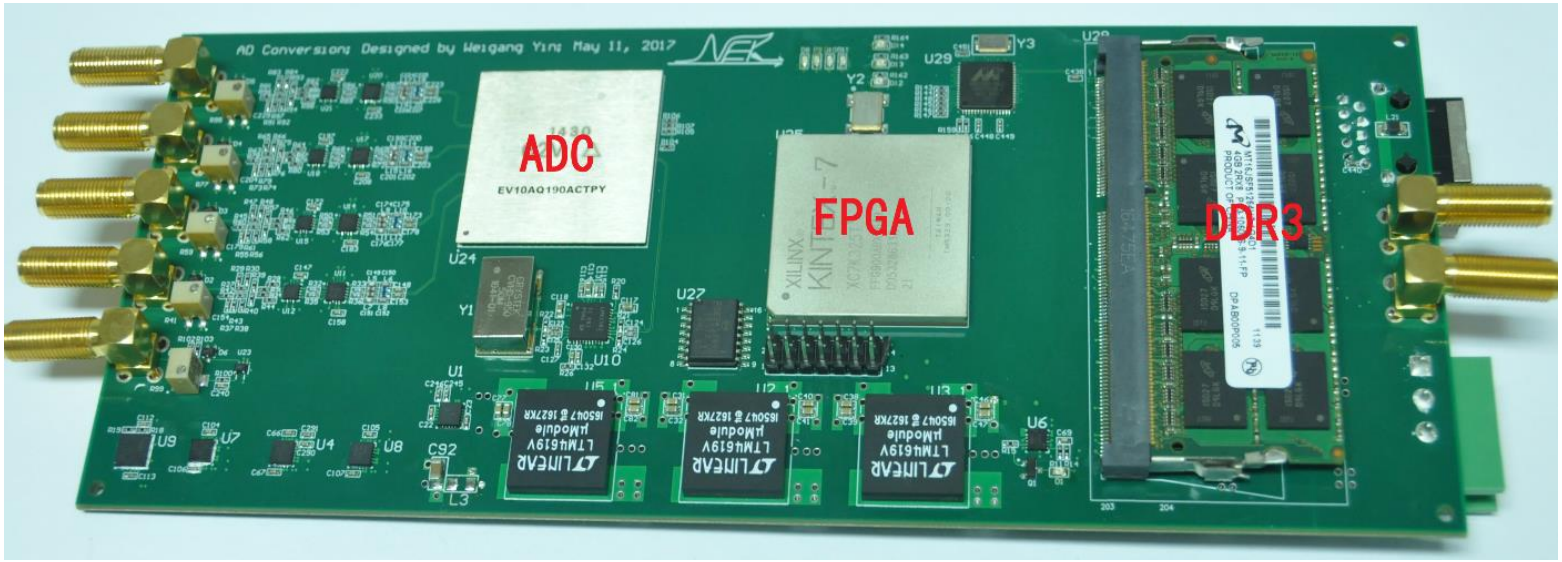
Dynamic phase alignment (DPA) module:

position the captured clock edge in the center of the data eye to provide maximum margin

User datagram protocol (UDP):

higher transmission efficiency and lower resource consumption than TCP

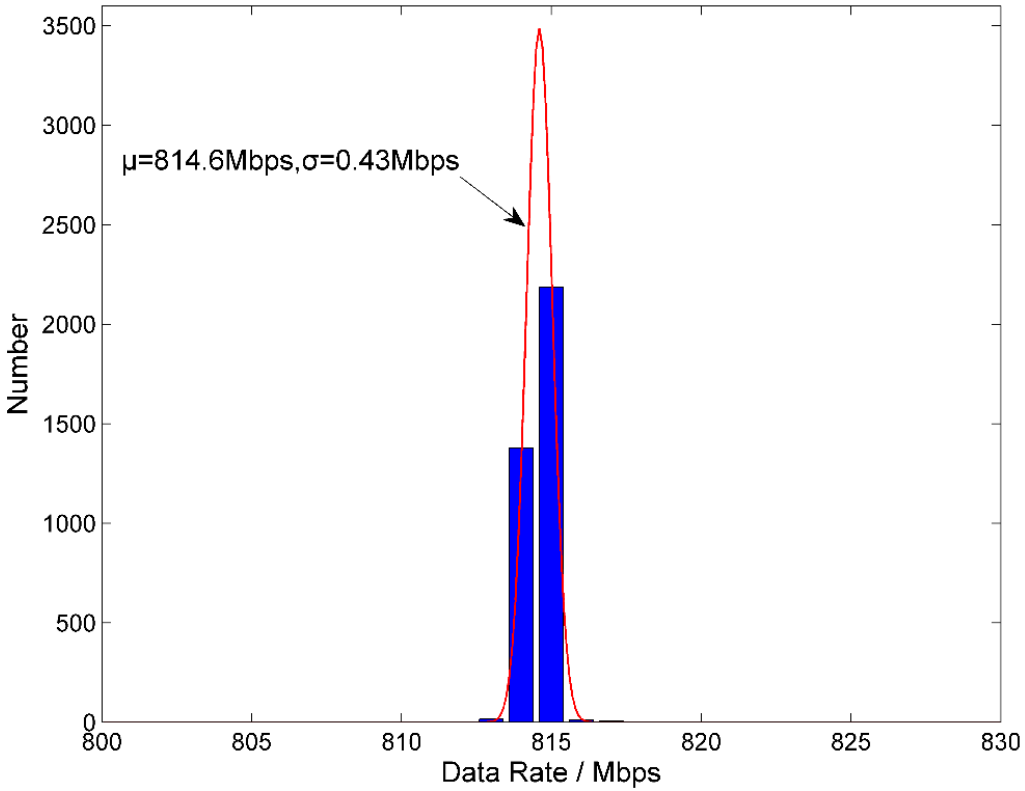
PCB of the Prototype



Features:

- **Size: 21*8.4cm**
  able to be installed in a limited space and easy to be shielded
- **Peak power consumption~16W Sleeping mode<5W:**
  no additional cooling measures other than the passive ones (heat sinks and heat conduction rubber)

Gigabit Ethernet Test



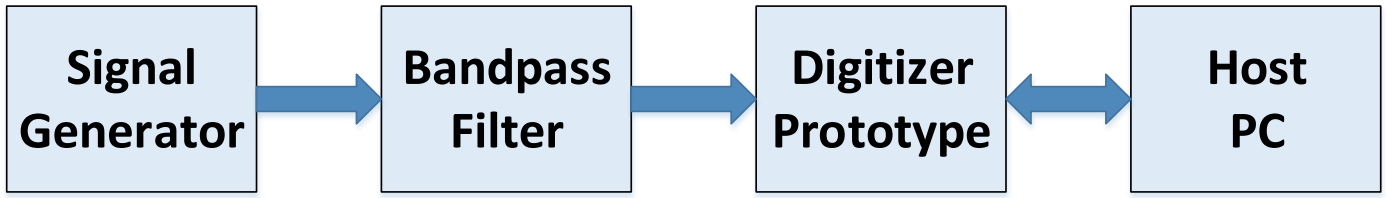
The prototype reply 256 packets of data for each date request command from PC

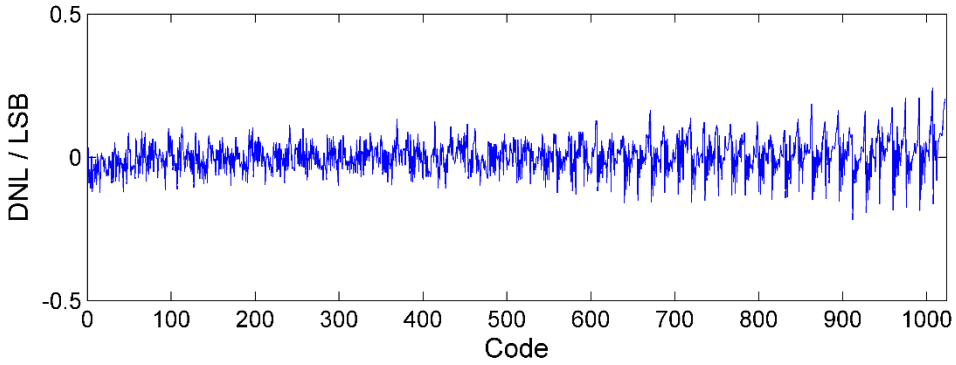
Each packet contains 1024 bytes user data

A counter outputting the binary code is used as data source

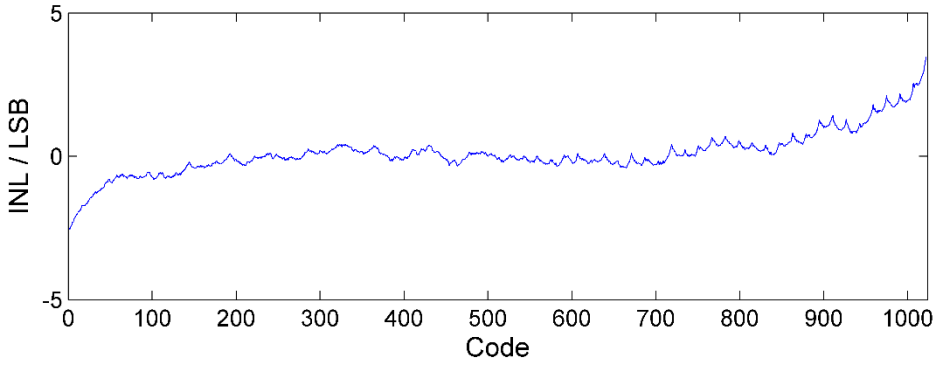
no packet loss and error code within 10 h

Static Performance Test





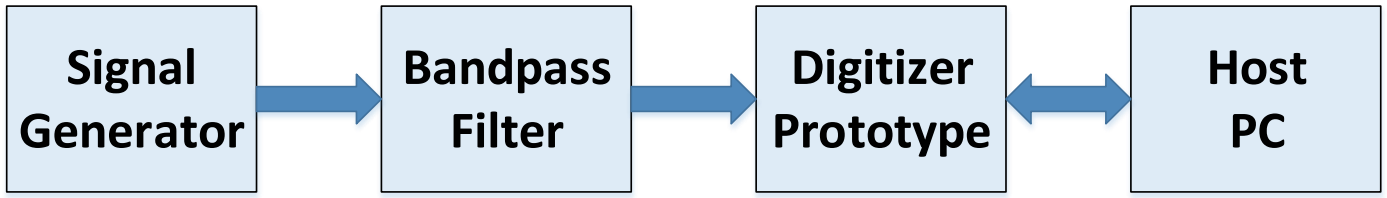
DNL:
ranges from -0.22 LSB to +0.24LSB

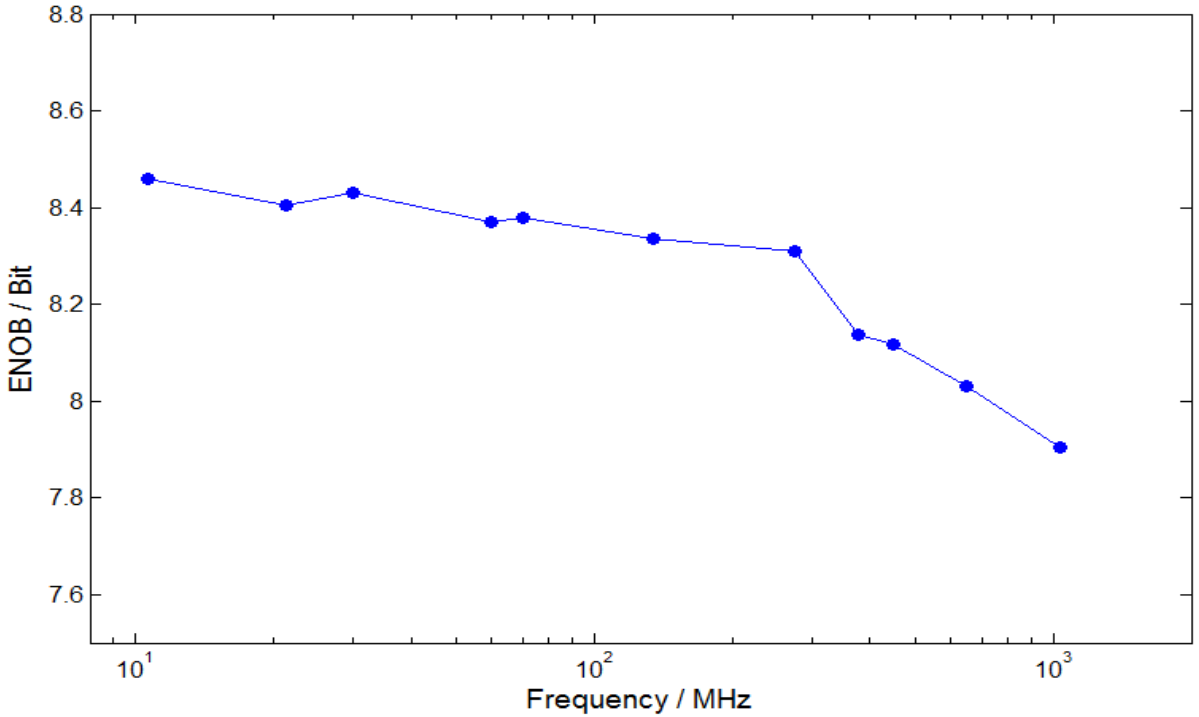


INL:
ranges from -2.53 LSB to +3.47LSB.

Code density method

Dynamic Performance Test





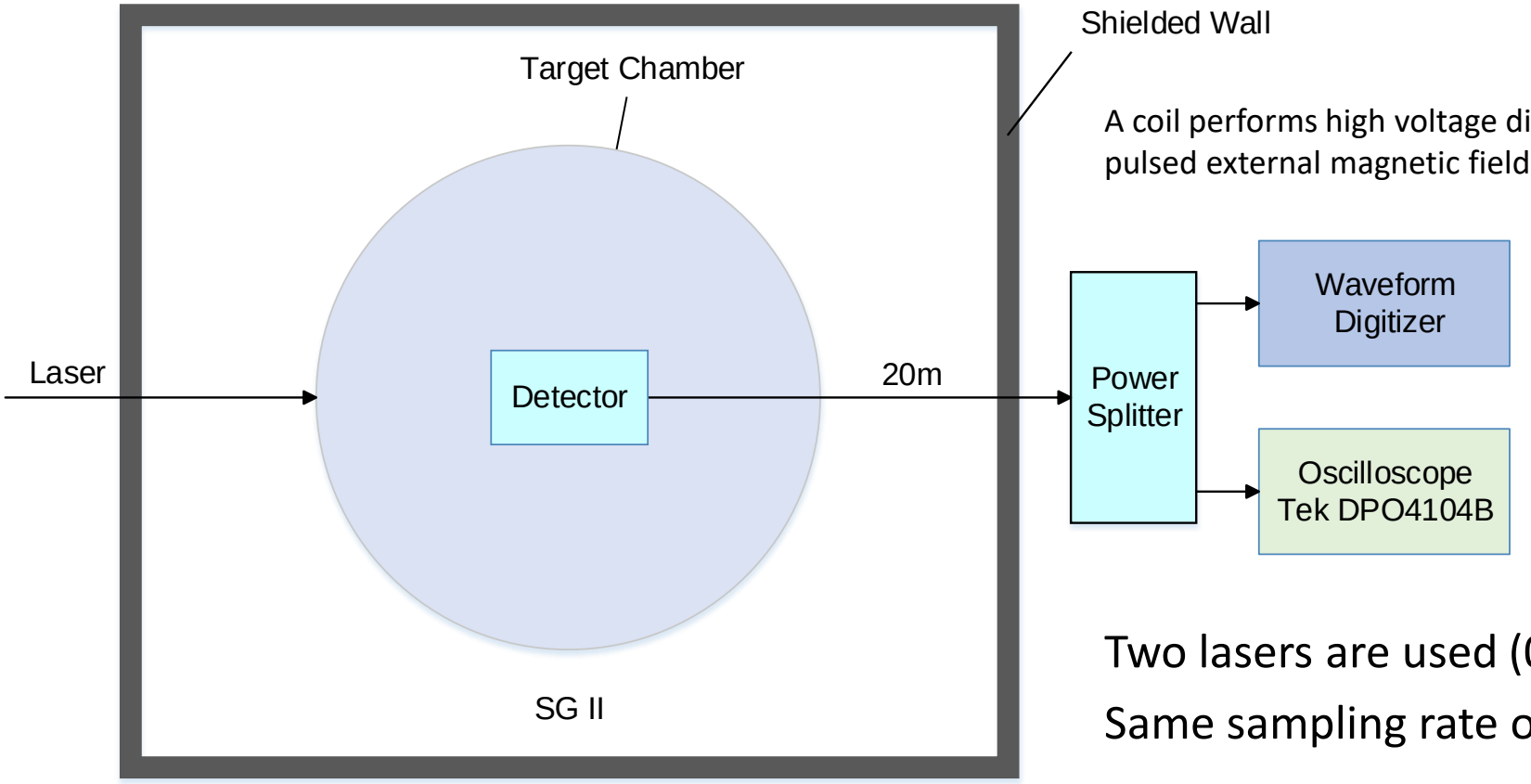
Sine wave signals :
10.7MHz to 1034MHz

100 000 sampling point

Fast Fourier Transform(FFT)

ENOB reaches 8.4 bits at 10.7MHz, drops to 7.9 bits at 1034MHz

Experiment and Comparison

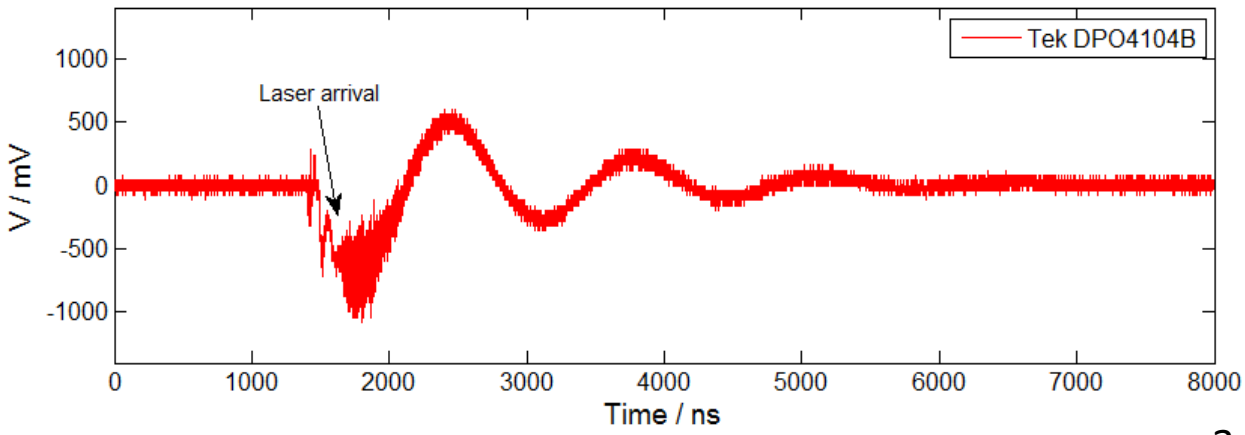


Two lasers are used (0.3 pw)

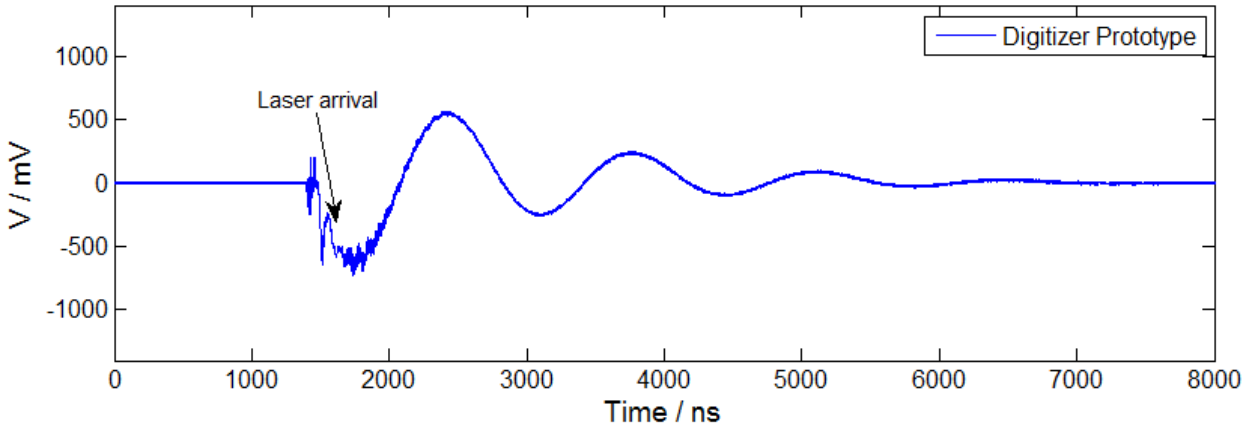
Same sampling rate of 5Gsps

Magnetized laser plasma with pulsed external strong magnetic

Experiment and Comparison



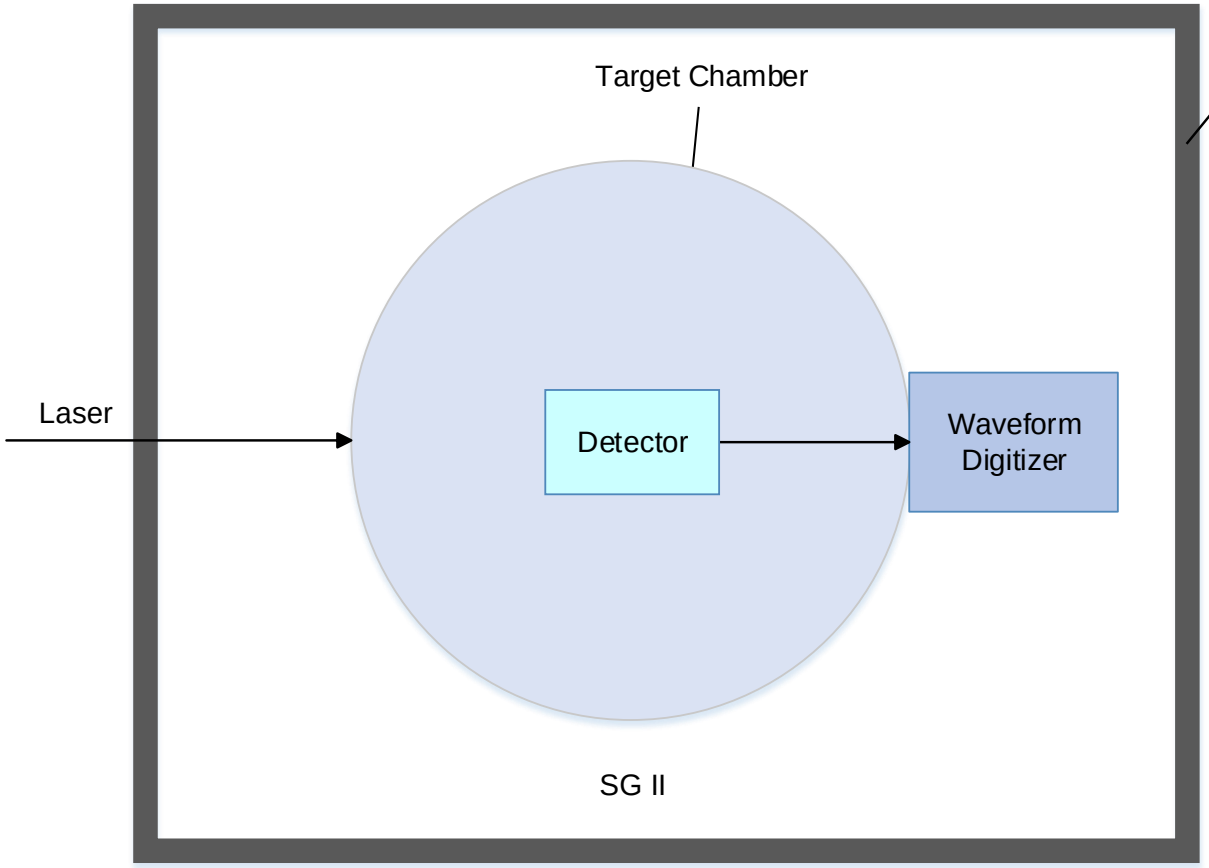
a damped sine signal



Prototype and the oscilloscope are placed outside the shielding wall

Prototype has lower baseline noise, stronger resistance to radiation interference.

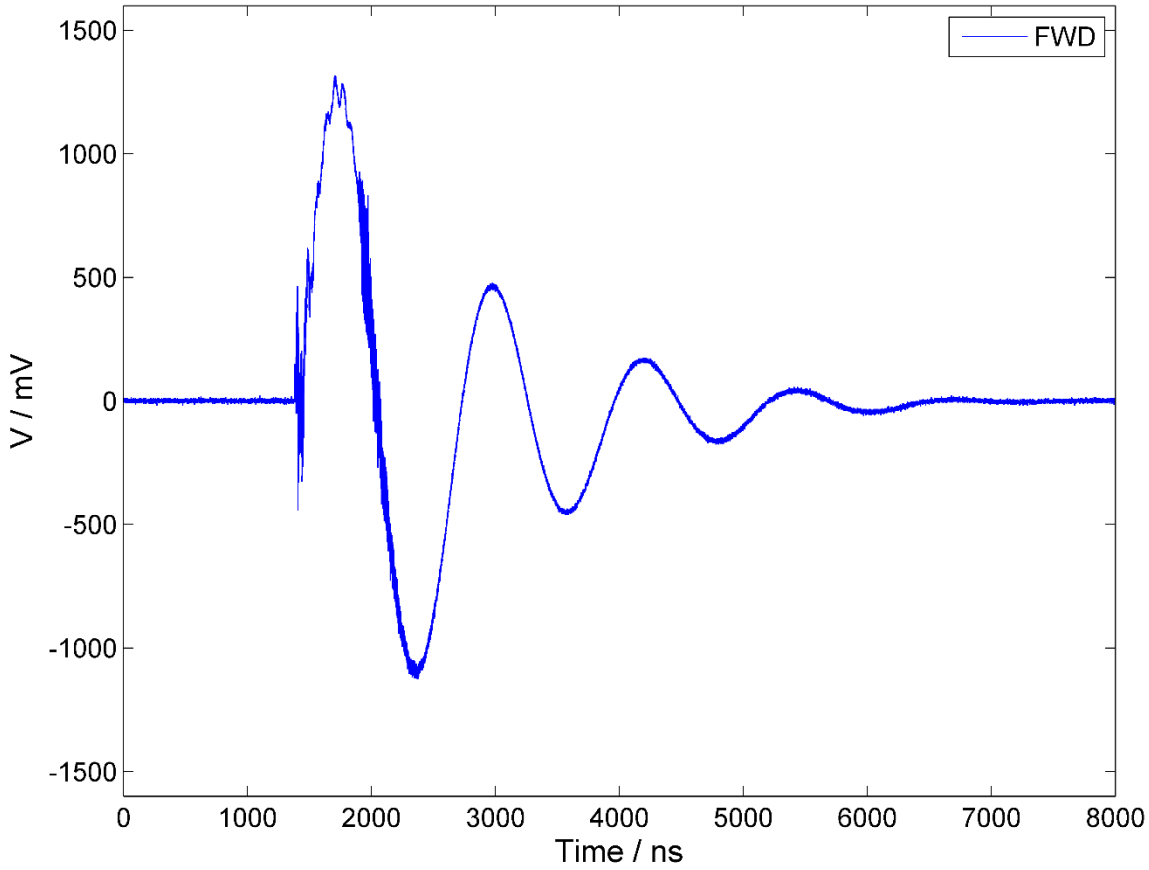
Experimetn and Comparison



Laser power=0.3 petawatt

Magnetized laser plasma with pulsed external strong magnetic

Experiment and Comparison



Prototype is placed inside the shielding wall

Prototype withstands the strong radiation on frond end and works well

Summary

Waveform Digitizer Prototype:

- 5Gsps sampling rate and 7.9 bits ENOB within 1GHz
- higher accuracy and smaller volume than commercial oscilloscopes
- Able to work on front end after well shielded
- Provide a better choice compared with commercial oscilloscopes

NEXT:

- Improve the sampling rate and bandwidth
- Reduce power consumption and volume

THANKS !