



K.Ueno(KEK IPNS) electronics expert will join.

Radiation hardness and high rate tolerance new device and applications

radiation hardness of electric devices is challenge for high energy physics experiments

- Achieve practical use of new device

new FPGA with atomic switch technology

- promising radiation hardness
- R&D for application to practical use in higher energy experiments is about to start
- development tools for users is desired
- implementation of high speed optical link in near future

- Create new application by combining existing ideas

Neutron and Gamma-ray Irradiation Effects on Atom Switch-based FPGA
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1. Introduction
 Trend in particle physics using accelerator
 Improvement of accelerator
 Increase in intensity, luminosity, energy → Detectors and related electronics including FPGA must be tolerant to higher radiation environment.
 Radiation effect
 • Neutron
 - Soft error: Single event upset (SEU)
 -> need investigation of SEU rate and development of SEU detection/correction scheme especially for FPGA
 - Hard error: Displacement damage dose (DDD), Type inversion
 -> need irradiation test
 • Gamma-ray
 - Hard error: Total ionizing dose (TID)
 -> need irradiation test
 Atom switch-based FPGA is one of the FPGAs which is expected to be used in higher radiation environment.

2. Atom switch-based FPGA (AS-FPGA)
 Atom switch (AS)
 Conductive bridge is formed in polymer solid electrolyte between inert Ru and active Cu electrodes.
 Specifications: extension time: > 10 years, resistances: ON/OFF ~ 2k/200M Ω, Switch capacitance: < 0.2 fF, # of rewriting times: > 10¹², SEU free in principle.
 AS-FPGA
 AS was successfully applied in FPGA for its routing switch and look-up tables [1,2]. AS-FPGA was already irradiated with heavy ion and pulsed laser, and the SEU tolerance was confirmed [3].
 For the accelerator experiment, more studies with the higher radiation environment are needed.

3. Irradiation tests
 AS-FPGA was irradiated with neutron for SEU and DDD investigations and γ-ray for TID.
Neutron irradiation tests
 Facility: Tandem accelerator @ Kobe Univ.
 • Beam: 3 MeV deuteron
 • Target: Be (φ20-mm)
 • Neutron energy: 2 MeV (c7 MeV)
 • Flux: 4.3x10¹⁰ Hz/cm² @ 10cm from target (beam current = 1 μA)
 Reactor @ KUR
 • Method: Pneumatic Tube
 • Rated thermal power: 3 MW
 • Neutron energy: broad
 • Flux: > 10¹¹ Hz/cm²
Gamma-ray irradiation tests
 Facility: RI Center @ Tokyo Institute of Technology & QST
 • Src: Co-60
 • Dose rate: 500 Gy/h
 • Total dose: 10 kGy
Measurements & results
 For SEU
 - W/O applying voltage
 - Fixed ON/OFF bit pattern was checked before and after irradiation of 1.2 x 10¹² n/cm²
 - Real-time meas. w/ applying voltage
 - Signals in 2 circuit chains with the same structure were compared during irradiation up to 10¹¹ n/cm².
For DDD
 - Leakage current check
 - AS-FPGA was irradiated with neutron of 10¹¹, 10¹⁰, and 10⁹ n/cm², and leakage current was evaluated. NO change was seen up to 10¹¹ n/cm².
 Leak current of AS-FPGA during irradiation compared with one of MAX3200 AS-FPGA can be used in higher radiation environment.
Summary & Future work
 • Radiation tolerant FPGA is needed in future particle physics using accelerator, and AS-FPGA is one candidate.
 • Neutron and gamma ray irradiation effects on AS-FPGA were investigated and it was found that AS-FPGA can be used in higher radiation environment.
 • More detailed studies will be done.
 • Prototype using AS-FPGA for particle physics will be constructed and evaluated.
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