Present Status of R&D for the warm linacs-2

K. Kubo (KEK)
Prepared with H. Hayano, T. Higo,

GLCTA (Global LC Test Accelerator) (X-band)
C-band Linac
Polarized electron source
ATF (Accelerator Test Facility):
  Low emittance beam
  Other R&D
ACFA LC Symposium (February, 2003)
GLC Project Report (Road Map Report)
ACFA, JHEPC, KEK

Contributors are from 120 institutes.

Australia, China, France, Filipinos, Germany, India, Japan, Korea, Russia, Singapore, Taiwan, Thailand, UK, USA and Vietnam

JLC -> G(Global)LC
**GLCTA: GLC Test Accelerator (X-band)**

**Purpose:**

1. **Structure High Gradient Test Stand**
2. **High Power Generation Demonstration**
3. **Main Linac Unit Demonstration**

Technology establishment and demonstration by KEK, universities, companies. Training, experience of people, students, companies. Will be one of R&D center for LC community.
GLCTA Located in the same building of ATF
System check was done. Problem: waveguide Breakdown -> Replace
New structure test started.
High Gradient Test started in Apr. 2004
Will be tested up to 65MV/m (Limited by input power ~63 MW)
High Power Generation

Solenoid Klystron #1+#2
Sep.2003 (for Structure test)

PPM Klystron #3 and #4
Apr.2004~

SLED II
RF pulse compressor
Oct. 2004~

One more station: under discussion
**High Power Generation plan**

Staging Plan:

2004. 3:  New Modulator start-up

2004. 5~8:  3 PPM Klys processing

2004. 9:  Putting more Inverter PS for 2 Klys drive

2004. 10:  75MW Kly + SLED II (WR-90) start-up

2005. 1:  50MW Kly +50MW Kly + SLED II (WR-90)

2005. 1:  1 more Modulator start-up

2005. 4:  75MW Kly +75MW Kly + SLED II (over height WG)

2005. 4~8:  power distribution system to structure build-up
Main Linac Unit Demonstration Plan

6m Linac Unit: Dec. 2005 commissioning

1. 75MW + 75MW + SLED II power source
2. power distribution to structures
3. 8 of 0.6m Structure with active mover stage
4. LC spec. Quadrupole with cavity BPM and active mover stage
5. Possibility of beam supply:
   from ATF+B.C. (2.8ns, 20 bunch with LC spec. emittance)
   or
   from RF gun test stand (1.4ns, 192 bunch with 5µm emittance)
GLCTA Beam Line details
## Phase-I R&D Summary

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### C-band Klystron
- Life test >8000 hours, OK.
- Smart modulator-I using inverter HV charger.

### Klystron Modulator
- OK
- Three-cell cavity.
- 1 m long cold model.
- Tested up to 135 MW @ KEK

### RF Pulse Compressor
- OK
- Input: 45 MW
- Beam acceleration at 50 MV/m was done at ATF-KEK, with S-band model.
- HOM damping performance was proved by ASSET-SLAC test, 1998.

### Accelerating Structure
- OK
SCSS : SPring-8 Compact SASE Source

- **Low Emittance Injector**
  - **Short saturation length**

- **High Gradient Accelerator**
  - **Short Accelerator Length**
  - KEK C-band 35 MV/m x 30 m = 1 GeV (4 units)
  - 35 MV/m x 180 m = 6 GeV (24 units)

- **Short Period Undulator**
  - **Lower Beam Energy and Short Saturation Length**
  - with Kitamura's In-Vacuum Undulator : \( E = 6\text{GeV}, |u| = 15 \text{ mm}, |x| = 0.1 \text{ nm} \)
High Gradient Test

STRUCTURE LENGTH: 1.8 m LONG
ACCELERATING GRADIENT: 56 MV/m
DARK CURRENT ENERGY: 100 MeV (MAX.)
MONITORS:
- Faraday Cup & Pico-Ampere-Meter
- Current Monitor
- X-Ray Survey Meter
- Scintillator & Photo-Multiplier
- Profile Monitor & Video-Camera

We will start on March, 2004
Polarized Electron Source (Nagoya Univ.)

GaAs-GaAsP superlattice Photocathode

- Heavy p-doped GaAs 5nm
- GaAs$_{0.4}$P$_{0.6}$ 3nm
- GaAs 3nm
- GaAs$_{0.04}$P$_{0.96}$ Buffer 2 μm
- GaAs Substrate 350 μm

- Polarization 92%
- Q.E. 0.5% (Satisfy LC spec.)

Nanosecond multi-bunch beam production is possible. 1.4 ns spacing, higher peak current will be tested.
200keV Polarized Electron Source

Features of 200keV PES

- Load lock system
- Ultra high vacuum (~ $10^{-10}$Pa)
- Dark current < 1nA (@200kV)

- $3\text{MV/m}@$photocathode surface
- Two ceramics insulation
- Atomic hydrogen cleaning

Preparation system is always ground level in spite of 200kV running.

New cathode is prepared during operation.
200keV Polarized Electron Source
**Polarized electron source**

Achieved: Polarization 92%, Q.E. 0.5%,
   high current multi-bunch of 2.8 ns spacing using
   200 KV Gun and GaAs-GaAsP superlattice Photocathode.
   (1.4 ns spacing will be tested.)

Next target is ultra low emittance pol. e- source;
   Higher voltage/field Gun
   NEA(Negative Electron Affinity)-GaAs Cathode.
Reduction of dark current is the key.
   (if not, the surface will be damaged.)
Material and polishing of the electrodes has been studied.

Detail will be reported in WG (Polarization Session).
**ATF: Accelerator Test Facility (at KEK)**

*For testing Injector part of LC*

- **E=1.28GeV** (GLC: 1.98)
- **Ne=1x10^{10} e-/bunch** (0.75x10^{10})
- **1 ~ 20 bunches/pulse** (192)
- **Rep rate=1.5Hz** (100 ~150 Hz)
Low emittance in ATF Damping Ring

Low vertical emittance is essentially important for small beam size at IP. --> high luminosity

Emittance in Damping Ring (DR) [GLC/NLC design]

Injected to DR: \( \gamma \varepsilon_{x,y} = 1 \times 10^{-4} \) m

Extracted from DR: \( \gamma \varepsilon_x = 3 \times 10^{-6} \) m, \( \gamma \varepsilon_y = 2 \times 10^{-8} \) m

Dominant source of the vertical emittance in DR are

- Vertical dispersion
- X-y coupling
**Vertical emittance vs. bunch population**

![Graph showing vertical emittance vs. bunch population with markers for Day 1, Day 2, and GLC/NLC Design. The GLC/NLC Design is shown as a solid line.](image)

(We achieved low emittance well below the GLC/NLC design)
Intensity dependence is explained by intra-beam scattering, consistent with calculation.
High quality multibunch beam from RF-gun

- Beam Intensity
  \(~1\times10^{10}/\text{bunch}\)
- Normalized Emittance
  \(\varepsilon_y = 4 \sim 7 \times 10^{-6} \text{ rad.m}\)
- Bunch length
  \(\sigma_z = 3 \sim 6 \text{ ps}\)
- Energy spread
  \(dE/E = 2 \sim 3 \% \text{ full-width}\)
- Q.E. of CsTe cathode
  \(16\% \text{ initial, } \sim 1\% \text{ with RF ON} \& \text{ keep constant over few weeks}\)
**Photo-cathode RF-gun**

- **2,856 MHz**
- **~100 MV/m**

KEK ATF RFgun
May, 2003

Cathode block with CsTe coating

Cathode block

End plate with cathode block
Multibunch emittance in ATF DR

Monitors of MB (bunch-by-bunch) emittance
In DR: Laser-wire
Extracted beam: wire scanner

Problem of MB emittance

Vacuum level in DR: High intensity beam -> SR light ->
Gas from chamber wall
‘Scrubbing’ is going on for better vacuum
Big energy fluctuation

Coupled bunch longitudinal oscillation.
To be cured by feedback.
A thin wire of light is created in an optical cavity, consists of two mirrors. When the electron beam hits the wire, γ-rays are produced by Compton scattering. A scintillation detector detects gamma rays. The whole optical system is placed on a movable table. The beam size is measured in a manner similar to conventional wire scanners.
higher mode laserwire

- use TEM01 resonance mode in an optical cavity as a laserwire

Transverse profile in optical cavity

TEM01 mode has two lobe and a node
**TM01 mode laser wire:**
Bottom-peak ratio is sensitive to the beam size.
Better accuracy for small beam (beam size ~ laser size of TM00).

**beam experiment**

**Signal rate vs. laser wire position**

**TM01**

**TM00**
Diffraction Radiation (DR) experiment for non-invasive beam diagnostics

DR is emitted when a charged particle passes through the vicinity of a conducting target

(When a charged particle go through the metal surface: Transition radiation (TR))

beam diagnostics using DR
- non-invasive
- single path measurement
- large radiation angle

Angular distribution of DR from slit

 Beam size

$$\sigma_y = \frac{\gamma \lambda}{2\pi} \sqrt{\frac{(1 + t_{y_{min}}^2)\Lambda_{min}}{(1 + t_{y_{max}}^2)\Lambda_{max}}}$$
Anguler distribution of
  Transition radiation (beam hit the thin metal) and
  Diffraction radiation (beam thorough the slit of the thin metal)
Principle was demonstrated. Excellent result as first trial. Need to reduce background for practical use.
nm resolution Cavity BPM study
SLAC-LLNL-KEK

\[ f = 6.426 \text{GHz} \]

TM110 mode, single port coupling

*Highest resolution so far is 91 nm:*
suspected to be from mechanical vibration

June 2003
New BPM support/mover for nm resolution study

Very small internal vibration.
Relative movement of 3 BPMs ~nm.
--> Confirm nm resolution

LLNL Design
Installed in ATF bema line
First test in March 2004
ATF Plans for 2004

• **Multibunch emittance study**
  High current injection is started.
  Low Y emittance will be confirmed by Laser Wire.

• **nm resolution BPM test & demonstration**
  Development of new precise mover &
  new cavity-BPM electronics.

• **intra-pulse Fast feedback test & demonstration Polarized positron production**

• **Other instrumentation developments**
  LW, XSR monitor, ODR monitor, cavity-BPM,
  multibunch BPM, etc.