STF Introduction

H. Hayano, 07202013
ILC Accelerator Introduction
Birds View of ILC accelerator: compressed image

e+, e- Main Linacs

Energy: 250GeV + 250GeV
Length: 11km + 11km
# of MB-Klystron: 560 total
# of Cryomodules: 1680 total
# of Cavities: 14560 total
Main Linac Arrangement for Mountainous site Tunnel

- Central shield (3.5m)
- RF power distribution
- Cryomodule
- Accelerator tunnel
- Pulse power supply for klystron
- Multi-beam klystron
- Digital RF controls
- Klystron tunnel
Main Accelerator Module: Cryomodule

9 Superconducting Cavities in the 12m length, 1m diameter cryostat

ILC cryomodule (12.65m)

- Helium gas return pipe
- Liquid helium supply
- Superconducting cavity
- Thermal shield
- Input Coupler

©Rey.Hori/KEK

Cross-section from D. Kostin
Superconducting Cavity made by pure Niobium

Cooled down at temperature 2K, then become superconducting state.

Long lasting High Accelerating Field by small input RF power (RF wall loss is very small)

Helium jacket, magnetic shield, frequency tuners are installed around the cavity, then put into the cryomodule.
**Principle of Electron beam Acceleration**

- Electron beam
- Liquid Helium
- Acceleration Field

- Cooled down to 2K --> Nb cavity become superconducting state.
- Put microwave power --> accelerating field is generated inside of cavity.
- Direction of electric field on axis alternate by RF frequency.

- Microwave Power

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**TM_{010} \pi – mode**

1.300 GHz
STF Introduction
KEKにおけるILC試験設備の場所

空洞製造設備
STF
ATF/ATF2
超伝導RF試験設備
STF (Superconducting RF Test Facility)

30m x 60m 建てや
95m 地下トンネル
空洞内面の電解研磨処理

Electro-Chemical Polish
Use Sulfuric acid + HF mixture
Apply voltage
  between center Al electrode and Nb cavity
Optimize parameter for smooth surface
  without sulfur residual particle
voltage and temperature are key parameter
Successive rinsing is another key technology
クエンチ場所を特定するための温度センサーマップとX線センサーマップ

T-map & Xray-map, together with pass-band mode measurement, location of quench is identified. Inspection camera visualize what’s happen inside.
クエンチ箇所の局所研磨修理

Pit; appeared after bulk EP, limit to 16MV/m
- local grinding & EP
- 27MV/m
- additional EP
- 38MV/m

Bump at heat affecting zone, limit to 20MV/m
- local grinding & EP
- 30MV/m
- additional HPR and bake
- 34MV/m
Experience of ILC cryomodule technology

cryomodule assembly,
2k cryogenics technology,
low heat load technology,
cavity control for high performance for pulsed RF,
LLRF digital control technology,
RF power distribution, Qext control.

Loaded Q control using external phase shifter and reflector. +/-15% QL control was possible.

Cavity assembly in clean room

Cryomodule cold-mass assembly
Quantum-Beam Experiment
( STF Accelerator Injector-part commissioning )
**STF Accelerator Injector (Quantum Beam)**

**STF accelerator was constructed by Feb. 2012**

High-flux X-ray generation by inverse Compton scattering
10mA electron beam (40MeV, 1ms, 5Hz)
Laser accumulator by 4 mirror resonator head-on collision of beam and laser

Target flux: $1.3 \times 10^{10}$ photons/sec 1% bandwidth

Beam operation: March – December 2012
Addendum: 1ms beam acceleration in STF accelerator

40MeV, 1ms, 7.5mA Beam Operation

- Loss Monitor
- BPM signal (V1+V3)
- 9mA (peak current)
- 6mA (peak current)

* a sag of beam train came from Gun-laser profile
Achieved beam size at laser collision point
(target= 10-20µm)

Minimum beam size@WM-PRM-05

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<td>Stage Position</td>
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<td>Go To Beam Position</td>
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<td>Go To X-Wire Position</td>
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<td>Go To Y-Wire Position</td>
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<td>Signal</td>
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<td>N/A</td>
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<td>σx: 17.5[µm]</td>
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Minimum beam size@WM-PRM-07

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<td>Go To X-Wire Position</td>
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<td>Go To Y-Wire Position</td>
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<td>Signal</td>
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<td>STAGE Control Panel</td>
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<td>N/A</td>
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<td>σx: 36.2[µm]</td>
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Achieved beam size at laser collision point
(target= 10-20µm)

Minimum beam size at WM-PRM-05

σx: 17.5[µm]

Minimum beam size at WM-PRM-07

σx: 36.2[µm]

Beam Line Layout

WM-PRM-05

mirror collision point

Laser collision point
4 mirror Laser Accumulator for Inverse-Compton X-ray generation
Initial set-up of 4-mirror cavity, summer 2012
Place MCP detector close to collision point (6m->2m)
Beam image and laser image at collision point (screen monitor)

Space matching was done by;
(1) Screen monitor,
(2) then, wire scanner with precision

After space matching, RF phase scan was done.
(between Laser phase and Accelerator beam phase)

Electron beam (40 bunches)

Laser beam (injected laser image, Not accumulated laser)
Typical Collision Condition

Electron Beam: 40MeV
- 248-bunch
- 55pC/bunch
- $\sigma_x : 43\mu m / \sigma_y : 55\mu m$

Laser: $\sim 15.4uJ@IP$
- $\sigma : \sim 80\mu m$

$\sim 2.7kW$
Compton Laser (Ext. Cavity) and STF accelerator frequency (162.5MHz) was not synchronized. The phase between Compton Laser and accelerator frequency is swept by 0-360deg. There is MCP count excess at around 80-90 degree.
Phase Scan (binning, beam charge normalized)

Subtraction
Laser OFF (Background) from Laser ON

Laser ON definition
Laser power > 70000 counts

Laser OFF definition
Laser power < 2000 counts
Signal Detected by MCP (22\textsuperscript{nd} Mar. 2013)

- 3-deg. 1-bin
- Laser Intensity Cut pick > 7000-ch (\~2.5kW) data

- 451-photon/train (MCP Aperture), with 248 bunches/train → 1.8 photon/bunch (1.5 \times 10^6 photons/sec for 1ms beam)
Detector Setup at QB accelerator

X-ray
(distance from collision point ~ 6m)

SOI

X-ray
NaI
(5mm-thick)

SOI (Silicon On Insulator)

Miyoshi
BG subtracted X-ray spectrum

~ 28 keV

SOI is energy calibrated at around 10-20 keV.

X-ray spectrum

[レーザーON] - [レーザーOFF]

クラスタサイズ <= 2
2000 (~100) trains
(SOI Bad data ~ 5%)
Summary Quantum-Beam Experiment

- X-ray signal was detected at STF Quantum-Beam Experiment. Yield is 1/1000 to 1/10000 lower than the target yield $10^{10}$, because of beam size, laser size, and laser power.

- Big contributions for X-ray detection were:
  - mechanical stability improvement of 4 mirror mount including feedback electronics improvement,
  - expanding chamber aperture to improve S/N ratio.

- Spectrum by SOI shows 28keV peak, consistent with calculation.
Cryomodule Status and Plans
STF Quantum Beam to STF Phase-2 Accelerator

STF Phase-2 Injector part (Quantum Beam Experiment)

STF Phase-2 Accelerator Plan

Disassemble in 2013 Summer

CM-1: ILC type cryomodule

CM-1: 13m  8 cavities + SC Q-magnet • BPM
First ILC-type Cryomodule in the world (magnet in the center)

Assembly in 2013, cool-down and beam operation in 2014–2015

Issues to be solved: cavity gradient degradation, alignment preservation, low heat load, cost-down assembly, beam acceleration operation by digital LLRF
Powering scheme of STF phase-2 Accelerator

ILC-type RF power distribution (TDR scheme)

Use of 10MW Multi-beam Klystron (MBK)

Now MBK is driven by Inverter PS HV modulator + Pulse trans. Will be replaced by Marx Modulator.
Cavity plan for cryomodule

All cavities must be HPR (High-Pressure code Regulation) clear

Cryomodule | Cavities
--- | ---
CM-1 (8 cavities) = 8 cavities selection from MHI-014 to MHI-022
CM-2a (4 cavities) = 4 cavities from MHI-023 to MHI-026
CM-2b (4 cavities) = 4 cavities selection from new bidding, KEK fabrication, other collaborators
CM-3a (4 cavities) = 4 cavities selection from new bidding, KEK fabrication, other collaborators
CM-3b (4 cavities) = 4 cavities selection from new bidding, KEK fabrication, other collaborators

Next Fabrication
(1) One more MBK (Multi-beam Klystron) will be procured in 2013.

(2) DTI Marx Modulator (collaboration with SLAC) will be tested in 2013 September.

(3) Japanese Marx Modulator will be fabricated in 2013 - 2015.

(4) TDR power distribution will be procured in 2014.

(5) Multi-cavity LLRF will be developed in 2014.
   (for 12 cavities, now 10 cavities max)
COI (Center of Innovation)
採択された事業

「地球を守るアース・クリーナー市場を創出する新産学連携拠点」

事業者: 高エネルギー加速器研究機構
拠点長: 鈴木機構長

連携企業: 三菱重工株式会社
株式会社 日立製作所
株式会社 東芝
三菱電機株式会社
京セラ株式会社
株式会社フジクラ

拠点計画の概要

地球を人類の永久の生存圏と可能ならしめるには、「地球汚染」「地球温暖化」「エネルギー不足」「自然資源枯渇」の問題克服が必須である。ここに、「新エネルギー輸送・変換」や「発電と河川・大気浄化の融合」などの「地球を浄化する」ニーズが生まれる。
本拠点では、超伝導加速器技術と量子ビーム技術を用いて、「地球を浄化する」技術とその事業化、市場拡大を促進し、「永久生存圏:地球を守る」課題に挑戦する。
新規施設

超伝導加速器利用促進化推進棟（新設）

革新的産学連携推進エリア

2013年整備

STF（既設）

STFトンネル（既設）

量子ビーム利用新機軸創出エリア
超伝導加速器を利用促進化推進棟の整備（最終形）
電解研磨設備の例

Saclay Vertical-EP
大型クリーンルーム設備の例

ISO-4, ISO-6クリーンルーム、空洞連結用レール2本

Sacaly cryomodule assembly facility
4台空洞用 縦測定設備の例

DESY AMTF
Saclay
cryomodule assembly facility
STF Plan
Overall Plans of ILC, STF

**ILC**
- GDE
- ILC new-scheme: Linear Collider Collaboration (LCC)
- Project approval
- Pre-ILC lab.

**STF**
- STF Accelerator Injector (Quantum-Beam)
- Operation (40MeV)
- ILC-type Cryomodule (CM-1) + CM2a
- Operation (418MeV)
- CM2b + CM3a + CM3b
- Test Facility construction
- Test Facility Operation

**CFF**
- Start-up by Cavity Fabrication (KEK-01, KEK-02, KEK-03)
- Production facility operation
- Industrialization and cost-down