ilc newsline

29 MARCH 2012

FEATURE

More knobs, more knowledge

Long-bunch-train ILC studies are back at FLASH

by Barbara Warmbein

In their unflagging quest to achieve higher gradients for the ILC, scientists in the 9-mA study programme at DESY's FLASH facility develop a better knack for automating accelerator voltages, helping keep cavity gradients high and the whole system stable.

AROUND THE WORLD

Triple milestone for Cornell's ERL programme

by Leah Hesla

Researchers at Cornell University's Energy Recovery Linac programme recently achieved three milestones in two months. One of them could lead to more reliable superconducting accelerator cavities.

DIRECTOR'S CORNER

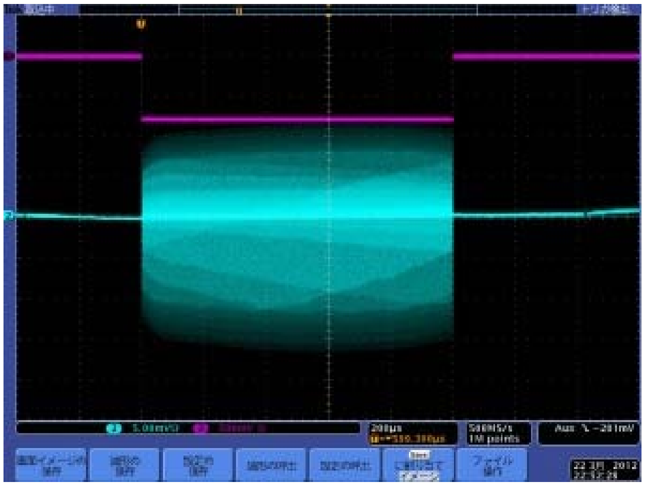
Advances in SCRF cavity performance in the Technical Design Phase

This week's issue features a Director's Corner from Akira Yamamoto, Project Manager for the Global Design Effort

by Akira Yamamoto

As a result of the continued improvement of cavity processing and a better understanding of the gradient limit, researchers are closely approaching their design goals, with the hope of reaching them by the end of 2012.

IMAGE OF THE WEEK



Extracting 1-millisecond beam

Image: H. Hayano

At KEK's superconducting RF test facility, better known as STF, scientists are conducting beam tests of their photocathode RF gun towards beam operation of the accelerator for the Quantum Beam Project. On 22 March, scientists succeeded in the extraction of a 1-millisecond beam for a 162.5-megahertz bunch train. Pictured here is a signal from the beam position monitor (blue) and a laser gate signal (violet).

Read more about the Quantum Beam Project in a future issue of *ILC NewsLine.*

IN THE NEWS

from ***CERN Courier***
27 March 2012
US high-energy physics faces budget cuts
The budget for the Department of Energy’s Office of Science would increase by 2.4 per cent to $4.992 billion, but high-energy physics would be reduced by 1.8 per cent to $777 million. …The proposed cuts in high-energy physics would hit two long-term programmes the hardest: the Long-Baseline Neutrino Experiment (LBNE) and the US R&D programme for the International Linear Collider (ILC).

from ***Nature***
26 March 2012
US physicists fight to save neutrino experiment
Bill Brinkman, director of the DOE’s Office of Science, wrote to Oddone to ask that Fermilab build the LBNE in stages. “I would like Fermilab to lead the development of an affordable and phased approach that will enable important science results at each phase,” he wrote.

from ***Science Insider***
22 March 2012
DOE Scraps Plans for Neutrino Experiment in Mine
At a projected $1.5 billion, the Long-Baseline Neutrino Experiment (LBNE) at the Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois, is not affordable, says William Brinkman, director of DOE’s Office of Science. So this week he asked physicists to come up with a cheaper way to do the same science.

CALENDAR

UPCOMING EVENTS

AIDA 1st Annual Meeting
DESY, Hamburg, Germany
28- 30 March 2012

Joint ACFA Physics and Detector Workshop and GDE meeting on Linear Collider (KILC12)
Daegu, Korea
23- 26 April 2012

ILD Workshop 2012
Kyushu University, Fukuoka, Japan
23- 25 May 2012

15th International Conference on Calorimetry in High Energy Physics (CALOR 2012)
Santa Fe, New Mexico
04- 08 June 2012

UPCOMING SCHOOLS

The 2012 European School of High-Energy Physics
Anjou, France
06- 19 June 2012

View complete calendar

More knobs, more knowledge

Long-bunch-train ILC studies are back at FLASH

FEATURE

Barbara Warmbein | 29 March 2012

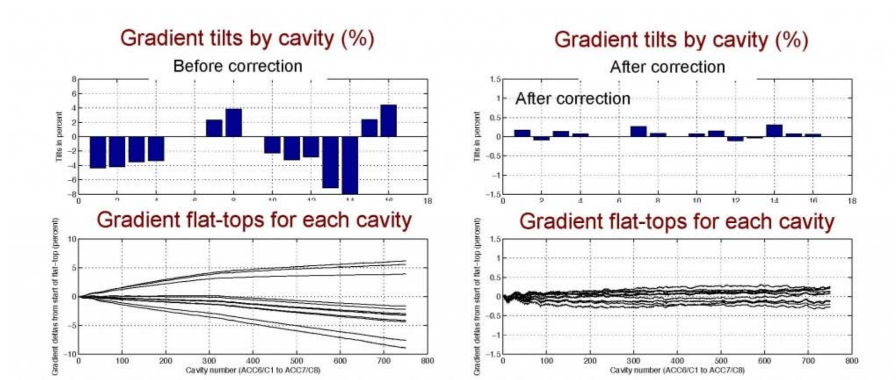
Julien Branlard, Nick Walker and John Carwardine discussing settings for the long bunch train studies in the accelerator control room at DESY. Image: Thies Rätzke

Accelerator theory and operating experience are all well and good. But if you're planning and researching the next-generation particle accelerator, you sometimes need to crank things to their limits in order to get a step further. The 9-mA team has descended again on DESY's FLASH accelerator in March to share control room space with the DESY operators, turn knobs and run programs that bring the 200-metre superconducting linac somewhat closer to how the ILC would run, delivering a wealth of data to the team and producing some very interesting results for FLASH operation as well.

The overall goal of the 9-mA studies is to run FLASH with long bunch trains and heavy beam loading, with cavities at the very top of their possible gradients and, accordingly, energy gains.

Tuning for maximum performance is an intricate interplay of information, with signals being fed back and forward to the knobs on each of the individual cavities so that all of them work together to reach the goal. It's no use if one of them runs off with a high gradient only to lose it again after a split second or, worse, quench and cause the whole chain to break down.

For the ILC to reach its intended performance, all the cavity gradients should be as flat as possible – meaning constant and stable – during the 800-microsecond beam pulse. If they change as a result of accelerating a train of bunches, some of the cavities could quench, forcing operators to run them at lower voltages and hence energy gain. During the studies in March, the team had set itself a goal of keeping gradients flat to within 1%: they reached 0.2% – much better than required.



From the studies summary talk: the iterative process of flattening cavity gradients

"It's all done by software that manipulates each cavity's individual setup, tailoring it to its optimal individual gradient and to the overall operating beam current," says study leader John Carwardine from Argonne National Laboratory, US. "First you calculate the optimal theoretical settings for the knobs we have (piezo tuners and power couplers), and with those you can get very close, but to really nail it the automated program found the right position by an iterative approach." Meaning: a software program turned a knob, had a look at the result, turned some more, had another look, and so on, until individual cavity as well as the total machine voltage (i.e. energy) were at top performance and the whole system stable.

For the ILC, this means that not only the acceleration simulation models are already very good and can be improved still further with the new data, but also that operators know more about the range of knob-turning that might need to be done – and that they would like to have a few more knobs to turn. “It would for example be good to be able to adjust the relative power to each cavity,” explains Carwardine.

DESY’s FLASH accelerator itself had received a few more knobs before this round of ILC studies, and is now also equipped with a control mechanism that can ramp down radiofrequency power if cavities approached their quench limit, providing a soft upper limit to the cranking the 9-mA team was planning to do. The electron gun can now produce 800-microsecond bunch trains (operated this time at 4.5 mA) instead of the 400-microsecond ones it generated the year before.

“Every time we have come back to do our studies the machine has behaved and performed better,” says Carwardine. For their studies they rely on the support from the experts at DESY, who were not simply present during the studies, but heavily involved in them. So the international team was happy to be able to give something back, namely the possibility that FLASH could routinely reach higher voltages and higher machine energy for its intended purpose: operation as a free-electron laser. Already the photons produced for user operation are of just short enough wavelength to penetrate the so-called water window (when water becomes transparent), a property that is very interesting for studying biological and chemical samples at FLASH. Getting to higher linac energies would produce photons with shorter wavelengths and better penetration of the water window.

Another milestone result for the recent round of studies had to do with power rather than voltage, or gradient, limits. Understanding how close the ILC will be able to run to the power limit of the source of the microwave power – the klystrons – has been an equally important R&D goal, since klystron power is the second largest cost driver after voltage. The study required some clever re-working of the klystron electronics to mimic the ultimate high-power performance demanded by the ILC. The initial results indicated that the beam can be stably controlled with the klystron running within less than 10% of its maximum output. To put it another way, over 90% of the klystron power can be used to accelerate the beam. This means that the currently foreseen number of klystrons in the ILC is sufficient to accelerate up to 9 mA of beam to the required 250-GeV beam energy.

In September the 9-mA team will have another chance to push the limits – the last one in time to provide results and input into the ILC Technical Design Report. The primary goals will be to take what has been learnt and push to a 6-mA beam current at the highest possible beam energies – and all of that at the turn of a knob!

Read more about ILC studies at FLASH here and here.

ACCELERATOR R&D | CAVITY GRADIENT | DESY | FLASH | KLYSTRON | LONG BUNCH TRAIN

AROUND THE WORLD

Triple milestone for Cornell's ERL programme

Leah Hesla | 29 March 2012

Cornell's first ERL cavity during its vertical test showing the required small energy loss. Image: Cornell / LEPP

Almost invariably, when superconducting accelerator cavities undergo performance tests, they present a dual personality that leaves researchers scratching their heads. When the niobium structure is stood upright (on a test stand), its quality factor mimics its posture – it measures high. But when the same cavity is placed horizontally in a cryomodule, its quality factor falls – often cut in half.

Scientists aren't sure why this happens, but to achieve the large quality factors needed for continuous-wave accelerators at Cornell University's ERL project, the effect has to be understood and eliminated. They may have eliminated one culprit in a recent horizontal cavity test.

Late last year Cornell's SRF group, headed by Georg Hoffstaetter, obtained a quality factor that prevailed against the usual drop. They found that their cavity prototype, once placed in the horizontal cryomodule, achieved a quality factor of 2.8×10^{10}, exceeding its vertical test stand value. The measurement was taken with hooked-up instrumentation, but without the input coupler and the higher-order mode absorber in place.

The quality factor, or Q, indicates how much energy is stored in the cavity versus how much is dissipated in one oscillation of the electromagnetic field. Higher Qs indicate less energy loss in the cavity wall and are therefore better for accelerating particles.

One hypothesis for the oft-experienced drop in Q says that dirt and other impurities settle in the cavity cells' equator regions, where there are large magnetic fields, when the cavity is laid flat. This dust could absorb energy, bringing down the Q. Cornell's cavity had consequently been assembled with great care for cleanliness.

The test is part of a research programme to pinpoint the cause of decreases in Q whenever a superconducting cavity is placed in a cryomodule. Cornell researchers will continue the programme for the next year, taking measurements of the 1.3-gigahertz cavity's Q at various points on its way to being fully equipped for an SRF linac.

"We want to see at what step of linac construction the Q factor gets worse, or figure out whether we can make the construction so clean that we can keep the Q above 2×10^{10}," Hoffstaetter said. "In the first stage of our test, we found that our cavity still had what we needed."

The result was one of a trio of milestones the Cornell team recently achieved for their energy recovery linac (ERL) research, an ongoing programme to build a low-energy-consumption, high-brightness, high-current ERL at the university.

The motivation behind the Cornell ERL is to produce exceptionally useful photon beams that would be applied in medicine, materials and industry.

Producing a low-energy-loss, and therefore less expensive, superconducting radiofrequency cavity is one major part of the ERL programme. Another involves producing a tight electron beam.

The dominant problem with making electron beams tight is that the particles repel each other because of their like charge. Overcoming this space charge problem to get a low-emittance (small-width) beam involves tricky magnet arrangements to focus the beam equally along the length of each particle bunch.

The goal for Cornell’s beam injector is to produce a 100-milliamp current with a 1.3-GHz bunch repetition rate. At a corresponding charge of roughly 80 picocoulombs per bunch, the strong space charge forces make it difficult to produce the necessary small emittances. Yet Cornell scientists skillfully honed a method for compensating for overly zealous particles in the bunch, bringing them into line.

In their second milestone, they achieved an emittance of 0.3 millimetre·milliradians at the full bunch charge of 80 pC for the core of the beam (or 75 percent of the particles). Their goal is to bring not only the core, but the entire beam down to the 0.3 mm·mrad value, improving the optics so that they can fold in all of the particles at the beam’s fringes.

The bunch repetition rate – and therefore the current – was reduced for this second milestone to preserve the emittance-measurement equipment. But Cornell researchers operated at the nominal 1.3-GHz rate in a third project to push at the high-current frontier.

Achieving yet a third milestone, they also generated a world-record current for any laser-driven photocathode electron gun. Their prototype injector reached a current of 50 milliamps – halfway to their 100-mA goal. To reach their goal, researchers still need to overcome a few challenges.

One is to figure out how to supply the high amounts of power needed to get the desired current without overpowering the couplers. They also have to keep the electron beam narrow and stable, which requires exquisite magnet alignment. A small beam halo and a narrow electron beam require that the laser beam hitting the photo-emitting cathode of the electron gun is also well focused and stable.

Their work seems to have paid huge dividends recently. At first efforts to boost the current progressed slowly, taking about two years to get to 10 mA and then a little more than a year more to double that value. Then, after putting more effort into properly aligning and stabilising the laser, magnets and other components, the current shot up to 50 mA in only six months. They’re now confident they’ll reach the 100-mA finish line.

Adding to the upbeat sense of accomplishment in scoring the ERL milestones was their unexpected, practically simultaneous arrival. The Cornell group reached all three in a brief two-month span.

“The time was ripe to reap the successes,” Hoffstaetter said.

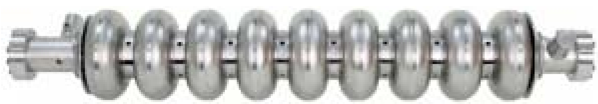
BEAM CURRENT | BEAM EMITTANCE | CAVITY DIAGNOSTIC | CAVITY PROCESSING | CAVITY TESTING | CORNELL | ENERGY RECOVERY LINAC | ERL | SRF TECHNOLOGY

DIRECTOR'S CORNER

Advances in SCRF cavity performance in the Technical Design Phase

This week's issue features a Director's Corner from Akira Yamamoto, Project Manager for the Global Design Effort

Akira Yamamoto | 29 March 2012

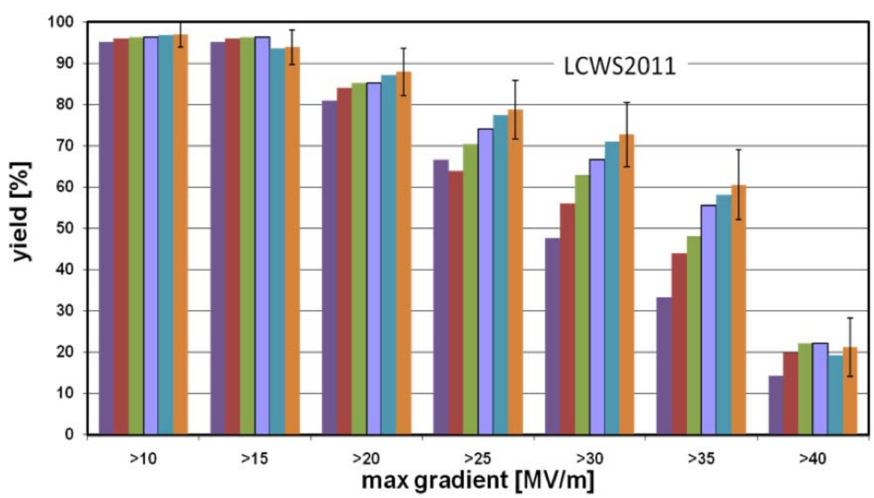


A 1.3-GHz TESLA-type nine-cell cavity

The current ILC superconducting radiofrequency (SCRF) cavity design is based on the so-called TESLA type (the elliptical shape as shown at left), a 1.3-gigahertz (GHz) nine-cell cavity. The design gradient has been set at 35 megavolts per metre (MV/m) and an average quality factor (Q_0) of greater than 8×10^9 to realise the stable, long-term operation at 31.5 MV/m with a Q_0 of $\geq 1\times10^{10}$. The SCRF R&D plan has been scoping to realise a successful cavity production yield of more than 50% as an interim milestone, and to reach a successful production yield of more than 90% by the end of the Technical Design Phase. To evaluate the progress in view of industrialisation readiness, a standard process for cavity fabrication and surface preparation has been settled, following a technical assessment given by the Tesla Technology Collaboration.

In the Technical Design Phase, we have established a clear definition of the production yield for a global database, adopting the yield measured after the first and second passes in the surface preparation process, after mechanical fabrication, as a rule for cavity qualification. The ILC cavity global-database team – consisting of members from Cornell, Jefferson Lab and Fermilab in the US, DESY in Germany, and KEK in Japan – took on the task of not only creating the database, but also defining rules for how the data should be included and how it would be presented. The figure below shows cavity gradient performance progress with production yield integrated over the period between 2006 and 2011. The first data-set was provided in October 2009, and the latest one in September 2011.

We now better understand how to improve the cavity gradient. For example, field emission has been much reduced thanks to new surface cleaning procedures such as ethanol rinsing and ultrasonic cleaning with detergent after the electropolishing (EP) process. A further reduction of field emission has been achieved by applying continued acid circulation during the EP process with a lower current density, resulting in keeping the cavity surface temperature lower. Optimised electropolishing and following streamlined cleanroom assembly guidelines resulted in a reproducible cavity process and hence reproducible cavity gradient results. As a



Cavity gradient performance progress with production yield for the second pass over the period between 2006 and 2011. The first data set was provided in October 2009 (violet) and the latest one in September 2011 (orange).

result of the continued improvement of the cavity processing and better understanding of the gradient limit, the gradient goal of more than 90% yield at 35 MV/m and Q_0 greater than 8 x 10^9 on average, allowing reasonable spreads, is being approached. Jefferson Lab is leading the way to reaching this goal with their own data set. The worldwide, general status in the production yield evaluation is summarised in the table to the right. Based on the recent decision to take a gradient spread of plus or minus 20%, we look forward to reaching the 90% yield as the SCRF R&D goal within the Technical Design Phase, and hence by the end of 2012.

Manufactured by:	Processed & tested by:	Integrated yield (b/t years)	Annual yield (in year)
ACC, Zanon	DESY, JLab	> 30% (2006-2009)	> 40% (2009)
ACC/RI, Zanon, AES, MHI	DESY, JLab, Fermilab, KEK	> 60% (2006-2011)	> 80% (2010-2011)

Progress in the production yield evaluation of nine-cell cavities for ILC SCRF cavity gradient of 35 MV/m

CAVITY GRADIENT | CAVITY R&D | QUALITY FACTOR | SCRF | SRF | TECHNICAL DESIGN PHASE