OVERVIEW OF SUPERCONDUCTING PHOTO INJECTORS

A. Arnold#, J. Teichert, FZD, Dresden, Germany

Abstract

The success of most of the proposed ERL based electron accelerator projects for future storage ring replacements (SRR) and high power IR-FELs is contingent upon the development of an appropriate source. Electron beams with an unprecedented combination of high brightness, low emittance (0.1 µm rad) and high average current (hundreds of mA) are required to meet the FEL specification [1].

An elegant way to create such an unique beam is to combine the high beam quality of a normal conducting RF photo injector with the superconducting technology to get a superconducting RF photo injector (SRF gun).

SRF gun R&D programs based on different approaches are under investigation at a growing number of institutes and companies (AES, Beijing University, BESSY, BNL, DESY, FZD, JLab, Niowave, NPS, Wisconsin University). Lot of progress could be achieved during the last years and first long term operation was demonstrated at the FZD [2].

In the near future, this effort will lead to SRF guns, which are indispensable devices for future LINAC driven FEL facilities. Based on most prominent projects, this contribution covers status and progress of the state-of-the-art SRF gun developments in the world.

INTRODUCTION

Today we know three different types of photo injectors: DC-photo injector (DC gun), normal conducting RF photo injector (NCRF guns) and superconducting RF photo injectors (SRF guns) but only one has the potential for future accelerators.

DC guns easily provided CW electron beams but the low electric field at the cathode surface and the short accelerating gap limit the beam quality and the extractable bunch charge. More information are provided elsewhere [3].

NCRF guns are the most advanced type of electron injectors. They produce highest quality beams. However their low duty cycle can limit the performance of superconducting accelerators. Efforts are under way to increase the duty cycle but at the expense of cooling requirements, higher klystron power and lower power conversion efficiency [4].

SRF guns are a consequential enhancement of NCRF guns. The merger between the established NCRF technology and superconductivity reduces dissipated RF power significantly and allows CW mode for high average current operation. By the way, an improved cathode life time is expected for free, because both the high cryogenic vacuum and the RF electric field in front of the cathode reduce the ion back bombardment.

The SRF gun concept was first proposed in 1988 [5]. Four years later first experiments were done at the University of Wuppertal [6]. In 2002 an important milestone was achieved. The successful operation of the DROSSEL SRF gun could be demonstrated at FZD for the first time [7]. Gained by this great success, several R&D projects had been launched worldwide. Most of them pursue different approaches to overcome the existing challenges for a successful high power operation.

One main unknown is associated with the cathode in the superconducting (SC) cavity. Here, the risk of surface contamination and a suitable cathode material with respect to maximum extractable charge and operational lifetime are still of main interest. But also the requirement of removable cathodes and the need for a clean room compatible choke filter around it, are technological challenges.

Beside the cathodes also the high average beam power up to one megawatt causes major problems. RF main couplers and sources in this class are available today only in the lower UHF band up to 700 MHz. Also the non-resonant higher order mode power of some hundreds of watts and beam loss in the per mille range are not negligible any longer.

In contrast to NCRF guns the emittance compensation by solenoid magnets around the cavity is not suitable. Instead, a SC solenoid magnet in front of the cavity, RF focussing by cathode recess and transverse electric mode focussing are proposed [8]. Finally, problems also arise from the cavity design itself that has to assure good beam matching, no multipacting, high mechanical stiffness and sufficient cleanability at the same time.

A growing number of institutes and companies have been and are currently been found to address all these problems. Today four approaches, mostly distinguished by the combination of cavity shape and cathode material are known:

- Normal conducting (NC) cathodes + elliptical cavity
- NC cathodes + DC gap + elliptical cavity
- NC cathodes + quarter wave cavity
- Superconducting (SC) cathodes + elliptical cavity

This paper draws a picture of the worlds SRF gun projects by covering the pros and cons and the present status of these different approaches. It is mostly focussed on the beam and cavity parameters that are well arranged of all mentioned guns in table 1. Details on available lasers or present cathode development are given elsewhere [9].

* We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 programme (CARE, contract number RII3-CT-2003-506395), and the FP7 programme (EuCARD, contract number 227579), as well as the support of the German Federal Ministry of Education and Research grant 05 ES4BR1/8.

* The author thanks all the colleges named in Table 1, for their support!

a.arnold@fzd.de

Table 1: Comparison of all known SRF gun projects and whose expected parameters. Most of the information were provided by the expert named first in the last row. Values taken from other reference are additionally marked by an index in the table. Values marked by # are calculated out of V_C and U. Values marked by * are calculated using P_{diss} & Q_0. Still open parameters are filled in with tbd (to be determined).

		Elliptical Cavity + NC cathodes			DC-SC	Quarter Wave SRF guns			Elliptical Cavity + SC cathodes	
Parameter	**Units**	**FZD**	**BNL/AES**	**HZB BerlinPro**	**PKU gun**	**NPS 500MHz**	**WiFEL 200MHz**	**BNL 112MHz**	**Pb/Nb hybrid gun**	**HZB HoBiCat**
Beam kinetic energy, V_c	MeV	9.4	2	≤ 3.5	5	1.2	4.0	2.7 [2]	~5	≤ 3.5
Max bunch charge, Q_{max}	nC	1 / 0.077	5 / 0.7	0.077	0.1	1	0.2	5 [2]	1	0.015
Norm. trans. emittance, $\varepsilon_{n,t}$	mm mrad	2.5 / 1	5 / 1.4	1	1.2	4	0.9	3 [2]	1	1
Average beam current, I_b	mA	1 / 0.5	50 / 500	100	1-5	1	1.0	-	<1 rather 0.1	0.0045
Peak current, I_{pk}	A	67 / 20	166 / 70 [10]	4	20	50	50	-	50	6
Photocathode		Cs_2Te	CsK_2Sb	CsK_2Sb	Cs_2Te	tbd	Cs_2Te	tbd	Pb	Pb
Quantum efficiency, Q.E.	%	1	18	10	1-5	tbd	1	tbd	0.0017	$5x10^{-2}$
Driving laser wavelength, λ	nm	263	355	527	266	tbd	266	tbd	213	260
Pulse duration (FWHM)	ps	15 / 4	30 / 20 [10]	≤ 20	5	10 – 40	0.1	270 [2]	<20	2 to 3
Bunch repetition rate, f_{rep}	MHz	0.5 / 13	10 / 704	≤ 1300	81.25	10^{-5} – 100	5	9.4 [2]	<1 rather 0.1	0.030
Gun frequency, f_0	MHz	1300	703.75	1300	1300	500	200	112	1300	1300
Operating temperature	K	2	2	2	2	4.2	4.2	4.2	2	2
Dissipated power, P_{diss} at the intrinsic Q_0 of	W	26 @ $1x10^{10}$	4.2 @ $1x10^{10}$	12.1 [1] @ $1x10^{10}$	-	8.6 @ $9.5x10^{8}$	42 @ $3.2x10^{9}$	16.6 @ $3.5x10^{9}$	143 @ $5x10^{9}$	12.1 [1] @ $1x10^{10}$
Active cavity length, l_{activ}	cm	50	9.5	17.1	41.7	8	19	20 [2]	18.4	17.1
R_{Shunt}/Q_0, r (R_{shunt} from acc. def.)	Ω	334	96 95.2#	189 [4], β=1 101.4#	418, β=1	185, β=1 176.3#	147.8, β=1 118.8#	126.8 126.6#	170, β=1 35.2#	189[4], β=1 101.4#
Transit time factor, V_c/V_0	TTF	0.715	0.888 [3]	0.54 [1]	0.74 [6]	0.94	0.98 (β=1)	0.99	-	0.54 [1]
Stored energy at E_{pk}, U	J	32.4	8.4 / 9.5*	14.8 [1]	-	2.6	107.2	81.4*	87	14.8 [1]
Electric cathode field E_{cath}	MV/m	30	20	≥ 10	~5 [6]	25	45	19.7	50 - 60	≥ 10
Peak electric field, E_{pk}	MV/m	50	35.7	≤ 50	31.8	44	59	51.3	50 - 60	≤ 50
Peak magnetic flux, B_{pk}	mT	110	74	116	74.5	69.1	90.7	97.8	104 - 125	116
Peak magnetic field, H_{pk}	A/m	87535	59000	≤ 92600	59285	55000	72165	78000 [2]	$(83 - 99)x10^3$	≤ 92600
Persons that provided the data via private communication		A. Arnold [1]	I. Ben-Zvi [2] M. Cole [3]	T. Kamps [4] A. Arnold [1]	J. Hao [5] F. Wang [6]	J.W. Lewellen [7] T.L. Grimm [8]	B. Legg [9]	A. Burril [10] I. Ben-Zvi [2]	J. Sekutowicz [11]	T. Kamps [4] A. Arnold [1]

NC CATHODE + ELLIPTICAL CAVITY

Pioneering work in the development of elliptical SRF injectors was mainly promoted by Dietmar Janssen. Today three laboratories, Forschungszentrum Dresden-Rossendorf (FZD), Brookhaven National Laboratory (BNL) and Helmholtz-Zentrum Berlin (HZB) picked up this concept for different beam parameters.

FZD 3.5 Cell - 1.3 GHz SRF Gun

The FZD gun is still the most advanced project. The development started in 1998. The great success of the first SRF gun electron beam in 2002 [7], led to the present injector design for the ELBE LINAC (**E**lectron **L**inear accelerator with high **B**rilliance and low **E**mittance). Within a collaboration of DESY, FZD, MBI and HZB a 3.5 cell TESLA shaped cavity, made from RRR300 polycrystalline bulk niobium was built (Fig. 1). The cathode insertion was designed for an easy exchange and precise positioning of Cs_2Te cathodes. Additionally, a resonant superconducting choke filter surrounding the cathode is needed to prevent RF leakage out of the cavity. Two TESLA type HOM dampers and one 10 kW CW FZD input coupler are attached to complete the design [10]. The predicted cavity parameters are summarized in table 1.

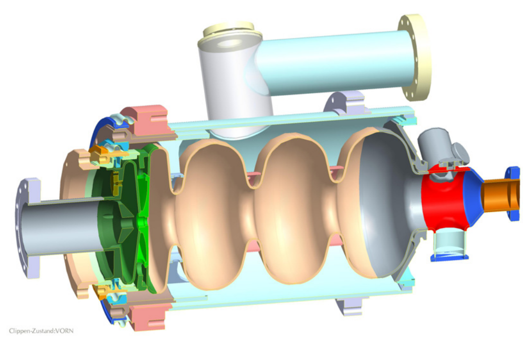

Figure 1: 1.3 GHz - 3.5 cell TESLA shaped FZD cavity.

The cavity was fabricated by Research Instruments (RI) and prepared two times at DESY and RI, respectively. During this procedure it became clear that the preparation (BCP and HPR) of cavities with choke filters is more difficult than the cleaning of standard TESLA cavities. For this reason the performance in all vertical tests was limited by field emission [12] [13].

The commissioning of this cavity started in September 2007. The Q_0 vs. E_{pk} measurement revealed that the intrinsic quality factor is 10 times lower than in the vertical tests and the achievable peak field is again limited by strong field emission. Nevertheless, after high power pulsed processing a stable CW operation up to E_{pk} = 18 MV/m at about 20 W dissipated helium power is possible.

Other cavity parameters like Lorentz force detuning, microphonics, helium pressure sensitivity, in-situ field distribution and tuner characteristics can be found elsewhere [14]. As predicted in simulations multipacting occurred in the gap between cathode stem and cavity. The onset level differs from cathode to cathode but by applying a DC bias up to -7kV the problem was eliminated.

The cathode preparation is done in - house using standard sequential deposition of Cs_2Te. Detailed information are reported in [15].

Beam parameter measurements were done at bunch charges up to 300 pC and 3 MeV of beam energy. The measured beam emittance, agree sufficiently with the ASTRA simulation performed at similar parameters. More details are given in [16] and [17].

In 2010, the 1mA high current operation and the connection to the ELBE LINAC are scheduled. In addition, the cavity performance will be improved by two new cavities fabricated at JLab [11].

One major conclusion today is, that even after two years of operation using four different Cs_2Te- and two metal cathodes (Cu, Mo), no performance degradation of the cavity could be seen.

AES/BNL 703.75 MHz – 0.5 Cell SRF Gun

The most challenging project is under investigation by collaboration of BNL and AES. Since 2004 a superconducting RF gun of several hundreds of milliampere is under development. The gun is planned to be the injector for electron cooling at RHIC, but there is also a great potential for high current injectors for LINACs driving MW-class FELs [18-22].

The RHIC cooler version (Fig. 2) consists of half cell superconducting cavity, operating at 703.75 MHz, two high power input couplers, a double quarter wave choke filter and a transfer mechanism for the electrically isolated and LN2 cooled cathode. The beam pipe diameter is increased to a cut-off frequency above the lowest higher order mode in order to use ferrite HOM dampers. The cavity specifications are summarized in table 1.

The main challenge is linked to the high beam current of 500 mA and bunch charges up to 5 nC. Much effort is been put into cathode R&D to achieve high Q.E. & operational lifetime. Promising results are obtained using CsK_2Sb. This alkali antimonide provides high current density of 1.3 mA/mm² and Q.E. of 12% @ 532 nm and 30% @ 355 nm are possible [23]. The vacuum required for long storage lifetime has to be in the order of ~10^{-10} mbar. Also the diamond amplifier concept makes great progress. Emission gain of 40 and current density of 20 mA/mm² were measured [24].

Another bottle neck arises by the very high average beam power of 1 MW itself. Couplers capable to transport 2x500 kW into the cavity are needed. In addition, a low penetration depth of the coupler tip to reduce transversal kicks and strong coupling of Q_{ext} ~ 3.7×10^4 are needed at the same time. Nevertheless also HOM damping (~500 W @ 1.4 nC) and beam loss in the per mille range are important issues.

In order to find principle design limitation two 1.3 GHz cavities were built and tested at 2 K. And in fact strong multipacting barriers appeared in the folded quarter wave choke filter [25]. Whose mitigation is planned by applying anti-multipacting grooves at the inner choke surface, use high temperature bake to reduce SEY and bias the cathode stalk compared to FZD.

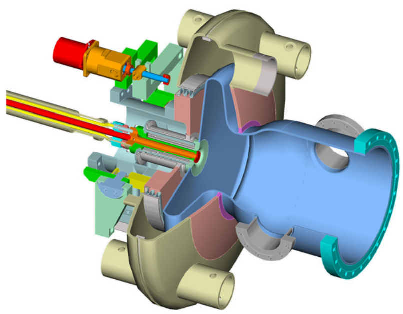

Figure 2: 703.75 MHz – half cell BNL/AES cavity. *Courtesy AES.*

Today the project is in a very advanced stage [26]. The injector fabrication is underway at AES. The vertical test bench at JLAB and the following hermetic string assembly are planned in the fall of 2009. The cryomodule completion is expected for spring 2010. The SC solenoid is already fabricated. In addition, the cathode transporter carts are delivered and the deposition system is tested up to 1×10^{-10} Torr. Lumera built a 5 W, 355 nm, 10 ps, 9.38 MHz laser system that is under commissioning now. The 500 kW CW coaxial couplers with "Pringles tip" are designed and fabricated by CPI and their conditioning will be done in - house using a 1 MW klystron.

In addition, a 1.3 GHz plug gun test system was built to investigate lifetime Q.E. and beam properties of GaAs under superconducting conditions.

HZB 1.3 GHz - 1.6 Cell SRF Gun

In the fall of 2008, Helmholtz Zentrum Berlin (HZB), formally known as BESSY, came to the decision to built B*ERL*inPro, an ERL test facility to demonstrate key ERL technologies and to establish ERL know-how at HZB [27]. Based on these experiences, then a layout of a full scale ERL-based next generation light source should be prepared.

B*ERL*inPro starts with the development of a 1.3 GHz 1.6 cell SRF photo gun using an embedded semiconductor cathode to achieve the high brightness (1 mm mrad) and high average current (100 mA). To push this ambitious goal, the expertise of the hybrid gun group led by Jacek Sekutowicz and the resources of HZB (HoBiCaT, beam diagnostics) and MBI (drive laser) are put together [28] [29]. In the first step, a 1.5 cell hybrid gun will be installed inside the HoBiCaT cryo vessel. The primary objective of this HoBiCaT gun is beam brightness. The desired target parameter to enter the next iteration level is 1 mm mrad normalized emittance @ 77 pC bunch charge. First beam operation is expected in late 2010. After successfully passing this baseline test, a 1.6 cell SRF gun with NC cathode stock and multi-alkaline cathode (CsK_2Sb) is in charge to demonstrate high average current operation for B*ERL*inPro (Fig. 3). The expected parameters for both cavities are listed in table 1.

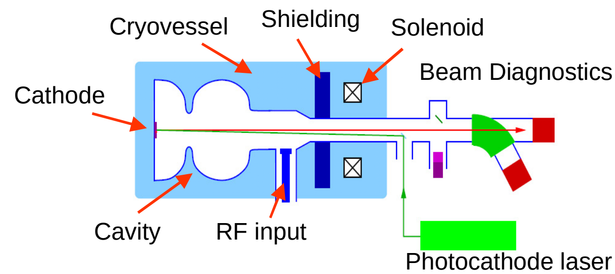

Figure 3: Generic design of the 1.3 GHz – 1.6 cell B*ERL*inPro SRF gun. *Courtesy Thorsten Kamps.*

NC CATHODE + DC GAP + SC CAVITY

IHIP PU 1.3 GHz – 3.5 Cell DC-SC RF Gun

The development of the hybrid DC-SC RF photo injector for PKU FEL started in 2001 at Peking University [30]. This alternative approach to overcome the contamination issue consists of a 100 kV DC Pierce gun directly connected to a 1.3 GHz superconducting cavity. The Cs_2Te cathode is exposed to a DC electric field used for extraction and pre-acceleration of the electrons, before they enter the boosting cavity through an 8 mm tube. The cut-off frequency of this tube is far above 1.3 GHz and thus the arrangement prevents RF induced losses and dark current at the cathode surface. It also reduces the risk for cavity contamination and spares the use of choke filters.

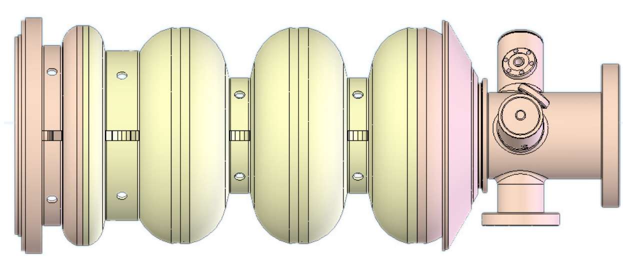

Figure 4: 1.3 GHz – 3.5 cell IHIP SRF gun cavity. *Courtesy IHIP PU.*

Due to the comparably weak pre-accelerating field the achievable beam quality is slightly reduced compared to the other SRF gun projects. The first test with beam done in 2004 [31] proved the feasibility of the injector concept but to fulfil the requirements for the future PKU-FEL an improved 3.5 cell cavity was designed and manufactured from large grain niobium (Fig. 4). The cavity successfully passed the vertical test at JLAB (E_{acc} = 23.4 MV/m @ Q_0 > 10^{10}) and also the cryostat including magnetic and LN2 shielding, tuning system, input coupler, liquid helium vessel and all supporting components is ready for final assembly [32].

After successful commissioning and beam test in 2010, the injector will provide electron beam to the IR PKU-FEL. The expected injector parameters are also listed in table 1.

NC CATHODE + ¼ WAVE SRF CAVITY

The youngest approach in the SRF gun community is the combination of quarter wave SC cavities and NC cathodes. Figure 5 - 7 show the three known quarter wave guns with frequencies between 112 - 500 MHz that are under development at Brookhaven National Laboratory (BNL), University of Wisconsin (UW) and Naval Postgraduate School (NPS). The cavity geometry allows a desired low frequency, while maintaining a reasonable small size which yields to the following advantages:

- more relaxed cryoplant operating temperature of 4.2 K (surface resistance scales with f^2)
- reduced RF losses at cathode (dielectric loss ~ f, skin effect ~ $\sqrt{f}$)
- reduced wake field losses and wake field induced emittance growth ($W_{\|}$ ~ f^2, $W_{\perp}$ ~ f^3)
- high transit time factor because of short acc. gap length compared to RF wavelength (λ/30 to 2λ/15)
- high power sources and RF couplers tested up to 800 kW @ 500 MHz CW

Multipacting has been shown not to be a critical issue in these structures as long as good processing procedures and operating vacuum levels are maintained. With respect to the demonstrated peak surface fields on the niobium of 100 MV/m and 200 mT at 1.8 K, typical design levels of half of these values are conservatively chosen for temperatures of 4.2 K. In all projects the cathodes are placed at the end of the inner conductor where the electric fields are largest. In addition, they are electrically and mechanically isolated and an operation at cryogenic to room temperature similar to the FZD gun is possible.

For emittance compensation the use of superconducting solenoids placed adjacent to the cavity and cathode recess are discussed. Simulations of all three guns have shown their capability to generate nC bunches with the very high brightness necessary for applications such as FEL's and high energy electron cooling.

NPS 500 MHz – Quarter Wave SRF Gun

NPS is currently developing a superconducting LINAC as part of their ERL FEL R&D test facility [33]. This test bed is mainly based on two Stanford-Rossendorf accelerator modules and a 500 MHz quarter wave SRF photo injector [34]. The gun string is shown in Fig. 5. Beside the typical components mentioned before, the NPS gun is equipped with an axial beam pipe RF coupler to reduce dipole kicks. The coupler is adjustable and also ensures good higher order mode damping.

The gun development is in an advanced state. The module design is finished and the cavity and also the SC solenoid have already been fabricated by Niowave Inc. Initial demonstration tests and experimental results are anticipated for 2010 [21].

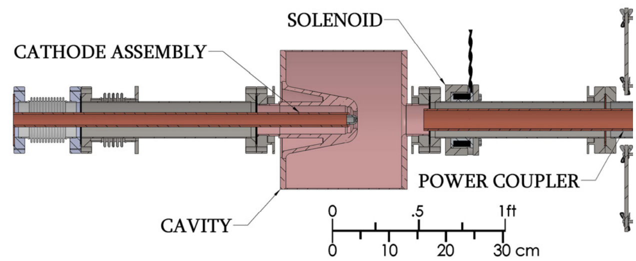

Figure 5: 500 MHz – quarter wave NPS SRF gun cavity string. *Courtesy NIOWAVE Inc.*

The beam parameters listed in table 1 are goals, not achieved nor necessarily achievable with the present prototype cavity. The photocathode choice has to be determined in large part. The cavity parameters are expected to evolve significantly with the next iteration of the prototype.

Future developments include coupling the quarter wave cavity to additional cells, investigations on high power input couplers with higher order mode extraction and cathode research using different electron emitters (photo, thermionic, field emission and secondary). Also the use of multiple modes and frequency operation for focusing and bunch length control can be explored.

Wisconsin U 200 MHz – Quarter Wave SRF Gun

University of Wisconsin - Madison, Synchrotron Radiation Center and MIT are developing a design for a seeded VUV/soft X-ray Free Electron Laser serving multiple simultaneous users. The present design uses an L - band CW superconducting 2.2 GeV electron LINAC to deliver 200 pC bunches to multiple FELs operating at repetition rates from kHz to MHz [35].

One main part of this project is the prototyping of a CW superconducting RF photo injector operating in the self-inflating bunch mode. Bunches are produced by a photocathode using a laser pulse of about 30 fs duration with a hemispherical transverse density distribution. The "charge pancake" produced by the laser pulse then expands under space charge forces to an ellipsoidal bunch with constant charge density. At the end of this process bunch peak currents of 50 A with less than 1 mm mrad normalized transverse slice emittance are anticipated including multi - megahertz pulse repetition frequencies.

The "blow out" mode requires a continuous electric field of about 40 MV/m on the cathode. To guarantee this demand, a 200 MHz superconducting quarter wave structure is proposed (Fig. 6). Beside the cavity, the design also includes the axial beam line coupler, the superconducting solenoid and the normal conducting cathode stalk that is electrically and thermally isolated by the RF choke and a thermal gap [36].

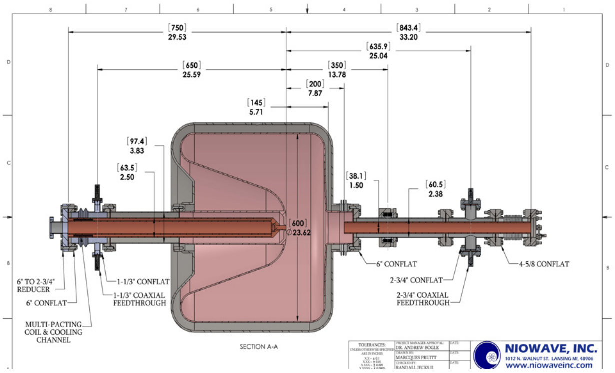

Figure 6: 200 MHz – quarter wave Wisconsin University SRF gun cavity string. *Courtesy NIOWAVE Inc.*

The low frequency offers the advantage of a very flat field profile in the accelerating gap and introduces less RF curvature on the bunch energy profile than an L - band device would can. This approach is less sensitive to errors in the drive laser timing and the lower magnetic field per MV/m ratio gives the potential to twice the peak electric fields compared to elliptical cavities. Operationally, the design is attractive because of its 4 K mode and the lower circulating RF currents in the cathode region, making a load lock and the RF choke much simpler. Again, the main parameters are summarized in table 1.

BNL 112 MHz – Quarter Wave SRF Gun

Beside the elliptical approach to design a high current SRF gun for electron cooling at RHIC, BNL also investigates a low-frequency quarter wave version to provide long electron bunches [37] [38]. In this concept even for high bunch charges, space - charge effects can be minimized and an electron beam of necessary quality can be provided to the cooling section.

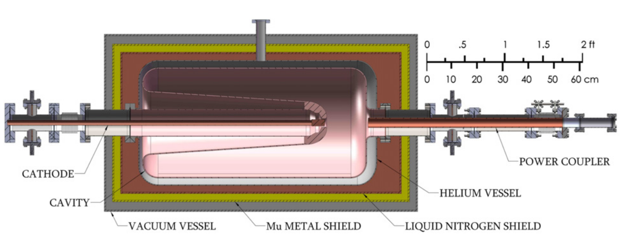

Figure 7: 112 MHz – quarter wave BNL SRF gun cavity string. *Courtesy A. Burrill.*

A prototype of such 112 MHz SRF gun (Fig. 7) is presently under construction by Niowave Inc. in Michigan [21]. The project is part of the DOE's Small Business Innovation Research (SBIR) and designed to be a proof of principle experiment to demonstrate the 4 K gun technology as application for low energy electron cooling.

Preliminary a gun exit energy of 2.69 MeV and a beer can laser size of R=5.5 mm, L=11.0° (270 ps, 8.14 cm full length) is proposed for 5 nC per bunch. Other important injector parameters are given in table 1.

SC CATHODE + ELLIPTICAL CAVITY

The technological difficulty of all three approaches mentioned before, is the integration of non superconducting cathode with its limited lifetime in a SC cavity. The cathode itself and also the complicated mechanism for the cathode exchange increases the potential risk of cavity contamination. So the assumption was that for milliampere - class SRF guns a superconducting metal cathode with its "infinity" life time simplifies the design while load lock systems and choke filters are not necessary any longer. First investigations at BNL measuring photoemission from bulk niobium result in QE < 10^{-5} @ 266nm. Due to this inappropriate value the concept of the Pb/Nb hybrid SRF injector using a superconducting lead cathode was proposed in 2005 [39].

1.3 GHz – 1.6 Cell Pb/Nb Hybrid SRF Gun

DESY, BNL, Stony Brook University, JLab, Institute for Nuclear Studies (INS) in Poland and SLAC collaborate to build a hybrid Pb/Nb SRF photo injector with lead spot as the emitter. Lead is a commonly used superconductor in acceleration, with a critical temperature Tc = 7.2 K not very different from niobium. The photo-emission properties of lead had been studied extensively in the past [40]. From these results lead appears to be an attractive option for moderate average current sources. The best measured QE between 0.2 - 0.3 % @ 213 nm would require 2.1 W to generate 1 mA. The optimal choice for a lead coating method seems to be arc deposition. Modest laser cleaning is sufficient to achieve the maximum QE without damage to the coating.

Figure 8 illustrates a proposed 1.6 cell low loss hybrid Pb/Nb gun design. The emitting spot of lead (Ø < 3 mm) is located in the back wall centre of the cavity. The coupler section is equipped with two HOM couplers, one input coupler and a pickup probe. In order to reduce transversal kicks a coaxial inset is planned. A solenoid, installed directly after the cavity, will be used for emittance growth compensation. All expected parameters are listed in table 1.

Baseline tests of two types of half - cell resonators to measure the QE of lead at 2 K and to test the RF performance of Nb/Pb cavities are reported in [41]. In order to improve lead coating and cavity cleaning, two half-cell and one 1.6 - cell high purity Nb cavities of the TESLA shape were built, additionally.

The cathode deposition of these cavities was done by the Soltan Institute using a mask for shielding the whole inner wall of the cavity except for the cathode location. After the coating the lead spot itself needs to be protected from the acid and water jets of the treatment procedure by another mask. The preparation and the vertical tests took place at JLab.

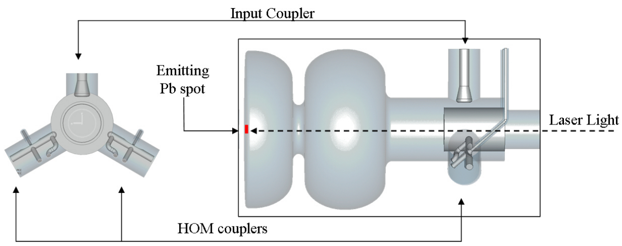

Figure 8: 1.3 GHz – 1.6 cell Pb/Nb hybrid SRF gun cavity. *Courtesy J. Sekutowicz.*

During the first vertical test after lead coating, Q-disease at all three cavities was observed. The hydrogen from the air intestinally dissolved in the heated niobium wall during the plasma deposition of the lead. In the second tests after improving the lead deposition, the performance of the two half cells was still not satisfactory but the 1.6 cell cavity achieved 46 MV/m without a significant Q degradation [42]. In the future further studies are planned on coating process, intrinsic Q and Q.E. variation during laser irradiation and finally also on coaxial coupling. A common goal with the BESSY group is the generation of an electron beam for emittance measurements in 2010.

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