COMBINED TARGET-COLLECTION SYSTEM FOR THE POSITRON PRODUCTION IN ILC

Alexander A. Mikhailichenko, Cornell University, LEPP, Ithaca, N Y 14853, U.S.A.

Abstract

We describe the positron collection system with Lithium lens, while one of the flanges of this lens made from Tungsten, which serves as a target for the photons radiated in a helical undulator by high-energy ILC beam.

OVERVIEW

Usage of Lithium Lens (LL) for positron collection was suggested years ago, see [1, 2]. Lithium lens with solid Lithium is in exploitation for decades now. Naturally, usage of LL for positron collection in a scheme with undulator [3], developed in Novosibirsk, included LL from the very beginning.

Usage of LL for positron collection still not a widely accepted idea, so the Novosibirsk lens remains the only one in operation. In recent times we applied some efforts to implement LL into ILC positron source [4, 5]. Development of the positron source for ILC includes collection optics with the flux concentrator also as it is now in a baseline design, described in [6]. Latest results on practical test undulator-based positron source demonstrated positron polarization ~ 80% and electron polarization ~90% respectively [7].

THE CONCEPT OF COMBINED LI LENS AND TARGET

The concept of the target combined with the Lithium lens, described in [2] is rather simple. In this combined assembly, the front window of the lithium container made from Tungsten, which serves as a target for the primary gamma (or electron) beam. Liquid lithium (melts at 180.54°C) serves as duct for the current and for the cooling purposes.

One peculiarity of conversion system with gammas is that the entrance side of the target not heated under exposure to the gamma flux as the number of charged particles (positrons and electrons) linearly increased along the target.

The concept of Tagger/Lens combined device under consideration is represented in Fig. 1. Front window made from tungsten (W). Outer window made either from beryllium (Be), boron carbide (BC), boron nitride (BN). Chemical formula of boron carbide is B_4C.

Window attached by flanges with OFC or annealed Nickel gasket ring. Usage of flange increases the thickness of package on ~5 mm total, which brings the total thickness of lens to ~2.54 cm.

Efficiency of positron capturing efficiency evaluated with the numerical code KONN (Monte-Carlo start to end simulator of undulator based positron source) shows, that LL adds, potentially, ~50% of positrons per each target station.

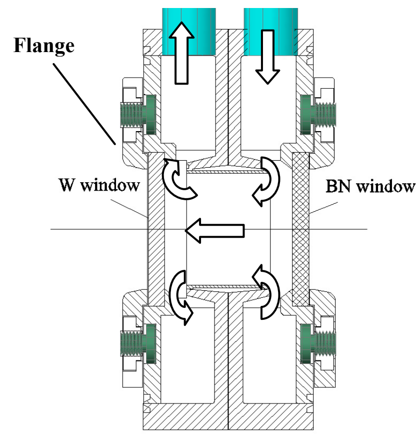

Figure 1: The concept of the target and Liquid Lithium Lens combined. The gamma beam is coming from the left. By arrows it is shown the liquid lithium flow.

LL DESIGN

LL case made from Ti, or from hot rolled 316 Stainless steel Reduced Activation Ferric (RAF) steel. This allows avoiding penetration of Lithium through the body of material, as Lithium actively reacting with Oxygen trapped in voids or dissolved in material. In our latest design we accepted classic collet-type contacting. This delivers compact design and possibility to quick re-assembling.

Liquid lithium will serve is this case for cooling W window as well. This might bring, potentially, big relief and design simplification for overall conversion unit.

Vacuumed transition combined with transforming from the strip line to a coaxial type of current duct. Electrical/vacuum insulation made with help of ceramic thick-wall cylinders.

For compensation of the force arising from atmospheric pressure, the second bellow is added from opposite side of the case. Additional ceramic cylinder (the very right in Fig. 3) serves for transduction of atmospheric pressure to the opposing side, so the system is balanced against atmospheric pressure.

LL case shown equipped with the current ducts and bellows, see Fig. 3. Lithium tubing here runs at one side. Cables are not shown in Fig. 4. Total number of cables caring up to 120 kA total is 15×4=60 (Fig. 4) so each cable caring <2kA in ~4 *msec* time duty. Solenoid participates in focusing of positrons after Lithium lens. We are considering the current duct between the pulser and the lens made as a strip line instead of many cables also. The choice will be made later on.

*Supported by ILC GDE Regional Directorship of America.

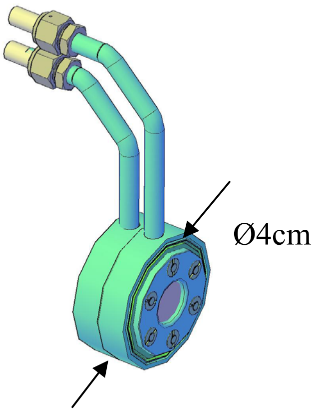

Figure 2: 3D view of liquid LL.

Usage of first (entrance) window made from tungsten allows working without rim (or any other) target at all.

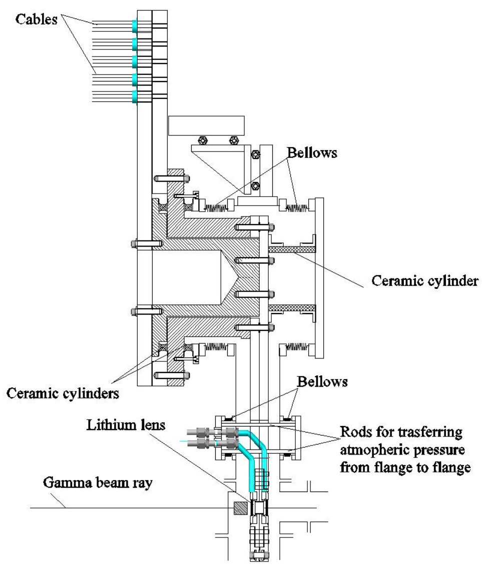

Figure 3: Transition to current duct and transition from vacuum to atmosphere for up to 150 kA line.

Mechanisms with stepping motors allow motion not only in the longitudinal direction (along the beam line), but in the transverse directions also due to flexibility of bellows under transverse deflections.

EFFICIENCY AND THERMAL REGIME

Efficiency calculated for the invariant transverse emittance 9*MeV*×*cm*, although dependence on emittance is slow down to ~6 *MeV*×*cm*. Dependence of polarization on LL radius is weak. Efficiency and polarization of captured positron beam calculated with KONN for different thickness of Be window indicate, that efficiency drops ~60% while the thickness of Be flanges approaches to 8 mm. However polarization here increases, so some manipulation of parameters of system allow play back efficiency on expense of polarization, so with 8 mm-thick Be flanges efficiency could be tuned back to 1.5 and polarization ~0.6 (60%) still guarantied.

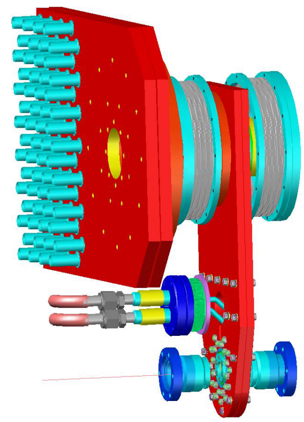

Figure 4: Isometric view of fragments from Fig. 3.

So we concluded that the thickness of out-window is not an issue here. Thickness should be determined by mechanical requirements only.

Some rise of polarization could be explained by scattering of low energy positrons, having lower polarization at the moment of creation.

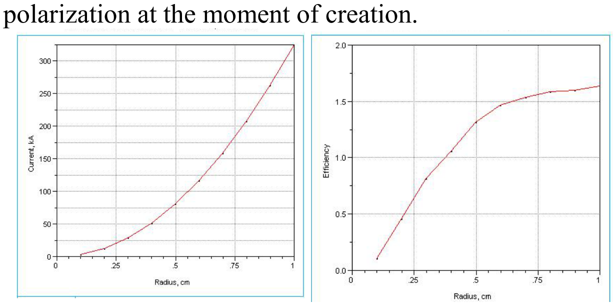

Figure 5: Total current running in Lithium rod (at the left). Efficiency as the function of radius (at the right).

Dependence on lens diameter represented in Fig. 5. During change of radius all other parameters, including gradient in the lens (which was G=65 kG/cm) kept fixed. So graph in Fig. 5 demonstrates quadratic dependence, naturally.

As the target is not spinning here, the thermal load applies to the same spot on the flange.

So the radius of the lens could be chosen ~0.65 cm, which will require current in the lithium rod I~137kA.

Gamma collimator uses a Pyrolithic graphite at front end and the Tungsten absorber at the exit end.

Utilization of two positron target stations with combining positrons in longitudinal phase space will allow doubling of positron production rate. In principle, two positron targets, even without any focusing at all, will allow to have the rate 1:2 (i.e. each initial electron or positron could create two positrons within acceptance of damping ring).

As the temperature of liquid lithium is ~190°C, technical solution could be easily implemented here. Pumping is going with the gear pump. Filling system consists of bellow filled with lithium and squeezed by the hydraulic pressure. All system and ducts wrapped by thermo-insulated sleeves.

Table of Parameters

Beam energy, GeV	100	150	250
Length of undulator, m	220	170	170
K factor	0.66	0.36	0.28
Period of undulator, cm	1	1	1
Distance to the target, m	200	350	600
Thick. of target/X_o	0.55	0.57	0.6
Radius of lens, cm	0.6	0.6	0.6
Gradient, kG/cm	60	60	65
Length of the lens, cm	0.7	0.7	0.7
Current, kA	108	108	117
Radius of collimator, cm	0.2	0.5	0.15
Rad, of irises in RF, cm	3	3	3
Rad of coll. before RF, cm	2	2	2
Acceptance, MeVxcm	9	9	9
Energy filter E> , MeV	51	54	63
Energy filter E< , MeV	110	110	180
ΔT per train 10^13 e-, ^{o}C	172	139	270
ΔT in lens from beam, ^{o}C	18	35	80
ΔT in lens from current, ^{o}C	90	90	100
Efficiency, e+/e-	1.52	1.57	1.52
Polarization, %	54	57	64

One positive aspect of such combination of target with Li lens is that the shock wave, generated by bunches fully absorbed in a liquid. In this case there is no zone with negative pressure at the exit surface of the target.

PULSER

Current running through the lithium rod could be 80-150kA with ~1 msec flat top, while its duty measured at the pedestal could be ~5msec. It combined with three odd harmonics.

Voltage required defined mostly by the stray (parasitic) inductance of transitions and, mostly by the transferring line. Although usage of transformer might be beneficiary here, we considering for the moment direct feeding in a view of well developed semiconductor commutators existence.

Reverse Switched Dinistors (RSD) for peak current from 200 kA to 500 kA and blocking voltage of 2400 V, encapsulated in hermetic metal-ceramic housing and without housing (RSD sizes of 64, 76 and 100 mm.

Pulser electrically insulated from the ground. LL has no contacts with ground also. This will help avoiding influence of high current pulse on surrounding electronics.

There is well developed technique for effective charge of capacitors with constant power for reduction of losses. In [8] the power supply able to feed lithium lens with current up to 1.5 MA and repetition rate up to several Hz.

SUMMARY

Angular spread of secondary positrons in undulator-based method is small. Even so, usage of lens allows increase of positron yield ~50% per target.

As the target is not in motion, the optimization carried for reduction of temperature jump in a target after passage of ~1013 primary electrons in undulator. This reduces slightly overall parameters of system, as with moving target, fully optimized, polarization could reach 70% with efficiency of e+/e- conversion equal 1.5.

Dependence of positron yield as function of Be window thickness is pretty monotonic. Be windows of up to 5 mm thick is possible. Usage of BC, BN windows allow have them thinner.

Current in LL one can expect not more, than 120 kA; for K=0.9 this comes to 50 kA.

Utilization of front window made from Tungsten potentially allows exclusion of target unit at al. Undulator with K=0.4 could be made with aperture diameter 8 mm, the one with K=0.9 will require aperture slightly less than 6 mm.

This type of lens/Target combined device might be recommended for the CLIC-type collider as in this case the power consumption in the target is minimal.

REFERENCES

[1] B.F. Bayanov et al., “A Lithium Lens for Axially Symmetric Focusing of High Energy Particles Beams”, NIM 190 (1981) 9.

[2] G.I. Silvestrov (Novosibirsk, IYF) , “Problems Of Intense Secondary Particle Beams Production”, 13th Int. Conf. on High Energy Accelerators, Novosibirsk, USSR, Aug 7-11, 1986, v.2: p. 258

[3] V.E. Balakin, A.A. Mikhailichenko, “Conversion System for Obtaining Highly Polarized Electrons and Positrons”, Novosibirsk, (IYF), INP-79-85, 1979. 12 pp.

[4] A.A. Mikhailichenko, “Lithium Lens (I)”, CBN 09-4, Cornell LEPP, Aug 2009, 17pp.

[5] A.A. Mikhailichenko, “Lithium Lens (II)”, CBN 10-3, Cornell LEPP, Aug 2010, 37pp.

[6] J.A. Clarke et al., “The Design of the Positron Source for the International Linear Collider”, EPAC08-WEPP155, Jun 25, 2008. 3 pp.

[7] G. Alexander et al., “Observation of Polarized Positrons from an Undulator-Based Source”, Phys. Rev. Lett. 100 (2008) 10801.

[8] A. Chernyakin, V. Eschenko, A. Khilchenko A. Kvashnin, Yu. Mukhoedov, G. Silvestrov, V. Zaytsev, “Pulse Power Supply System and Monitoring and Control System for Liquid Lithium Lens for Fermilab Antiproton Source”, Internal report BINP, Novosibirsk, 1998.