Bonn Polarized GaAs-Photoinjector

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ELectron Stretcher Accelerator
Electron Stretcher Accelerator (ELSA)

booster synchrotron
0.5 - 1.6 GeV

half cell of stretcher ring

stretcher ring
0.5 - 3.2 GeV
Conversion to $\gamma$'s via Bremsstrahlung
Electron Stretcher Accelerator (ELSA)

$I \leq 200 \text{ mA}$
$U \approx 50 \text{ kV}$
$\tau = 1 \text{ µs}$
$f_{\text{rep}} = 50 \text{ Hz}$
Generation of Polarized Electrons

GaAs

Operation, heat cleaning and activation in extreme UHV

Lifetime 1000 h $\leftrightarrow P(\text{H}_2\text{O}, \text{CO}_2) < 10^{-13}$ mbar
Highest Polarization

**Bulk GaAs**
- **Conduction Band**
  - $m = -1/2$
  - $m = +1/2$
- **Valence Band**
  - $m = -3/2$
  - $m = -1/2$
  - $m = +1/2$
  - $m = +3/2$

**Strained Layer Superlattice**
- **Conduction Band**
  - $m = -1/2$
  - $m = +1/2$
- **Valence Band**
  - $m = -3/2$
  - $m = -1/2$
  - $m = +1/2$
  - $m = +3/2$

$1.42 \text{ eV}$

$0.34 \text{ eV}$

$h\nu = E$
Typ. Photocathode Performance

Be-InGaAs/AlGaAs Superlattice

Typical Performance Parameters

- As protection layer
- Be-InGaAs $8 \times 10^{17}$
- Be-AlGaAs $4.75 \times 10^{17}$
- Be-InGaAs $5.39 \times 10^{17}$
- Be-AlGaAs $4.75 \times 10^{17}$
- Be-InGaAs $5.39 \times 10^{17}$

Effect of Wavelength on Photocathode Efficiency

- $P_{\text{max}} = 80\% \pm 1.5\% \text{ stat.} \pm 5\% \text{ syst.}$
Titanium-Sapphire-Laser

200mA @ 0.1%QE, $\tau = 1\mu$s:

$P_{\text{Laser}} > 300\text{W} \rightarrow 1\text{mJ/pulse}$

max. energy: 200mJ / pulse
Space Charge Limited Emission

**EGUN-Simulations:**

- Cathode
- Anode
- Beam
- $U_a = 48 \text{kV}$

**Measurements:**

- Graph showing electron emission and intensity over time.
- Graph showing emission current as a function of distance between cathode and anode.
The way to $10^{-12}$ mbar
Key to Success: H-Firing!
Vacuum in the Storage Chamber

important!
Electron Gun

Typical Mass Spectrum

Partialdruck / mbar

Spezifische Masse

H₂, He, CH₄, H₂O, CO, CO₂
Photocathode Preparation

• Cleaning of the PC’s surface:
  – heat cleaning at ~550°C:
    200°C: AsO
    350°C: As (from As₂O₃ + 2GaAs → Ga₂O₃ + 2As↑)
    500°C: Ga₂O
  – addition of atomic H:
    Ga₂O₃ + 4H → Ga₂O↑ + 2H₂O↑

• Activation with Cesium and Oxygen:
Heat Cleaning

Ircon Modline Plus Infrared Pyrometer

0.91 μm < λ < 0.97 μm
Hydrogen Cleaning

- Highly purified molecular hydrogen (99.9999%) from a gas bottle flows through a leak valve towards the heated palladium tube. The pressure is measured with a piezo gauge.
- Because only hydrogen passes through heated palladium, hydrogen without any impurities accumulates on the baked-out vacuum side of the tube. The pressure in this reservoir is measured with a piezo gauge.
- A calibrated leak valve is used to adjust the hydrogen flow through a capillary heated by electron bombardment up to 2000 K. There it is cracked into atomic hydrogen and is directed to the photocathode.
Load-Lock:

- Ladekammer
- Betriebskammer
- Quelle für atomaren Wasserstoff
- Präparationskammer
- Aufbewahrungs­kammer
Storage Chamber
Storage Chamber
Source of Polarized Electrons

Photocathode holder:

Specific features:
- inverted HV geometry
- adjustable perveance
- full load lock system
- H-cleaning
- $P > 80\%$ @ $E = 48$ keV
- $I = 200$ mA @ $\tau = 1\mu s$
- QE-lifetime $> 1000$ h
Source of Polarized Electrons

Specific features:
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200mJ Ti:Sa Laser
$E = 48 \text{ keV}$
$\rightarrow \beta = 0.4, \gamma = 1.1$

$P_{H_2O}^{(\text{LINAC})} / P_{H_2O}^{(\text{Source})} \approx 10^6$

Space Charge!
$F_{SC} \sim \rho / \gamma^2$
Electrostatic Deflector
Wire Scanner
Source and Transfer Line

\( E = 48 \text{ keV} \rightarrow \beta = 0.4, \gamma = 1.1 \)
Space-Charge dominated Beam Transfer at 48 keV

Transfer Efficiency > 99%

\[
\frac{d^2 x}{ds^2} + \left\{ k_x(s) + S(s) + T(s) \right\} \cdot x - \frac{\varepsilon_x^2}{x^3} - \frac{2\zeta}{x+y} = 0
\]

\[
\frac{d^2 y}{ds^2} + \left\{ k_y(s) + S(s) + T(s) \right\} \cdot y - \frac{\varepsilon_y^2}{y^3} - \frac{2\zeta}{x+y} = 0
\]
Bonn Polarized GaAs-Photoinjector

Workhorse since 2000:
- spin polarization $P > 80$
- pulsed beam current $I = 100\text{mA}$
- quantum life time $\tau > 3000\text{h}$
- transfer efficiency to LINAC $> 99$
- uptime close to 100%

- new load-lock with H-cleaning
- upgraded to pulse currents $I = 200\text{mA}$