An ultra-bright cold-atom electron source

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Introduction

Making use of **well established techniques** like:

- **Laser cooling and trapping**
- **Ultra Cold Plasma production (UCP)**
- **Pulsed high voltage acceleration**

We want to build an **ultra-bright cold-atom electron source**.

Applications:

- Compact X-ray sources
- To probe the structure of matter in physics, chemistry and biology
- Hard X-ray free-electron laser

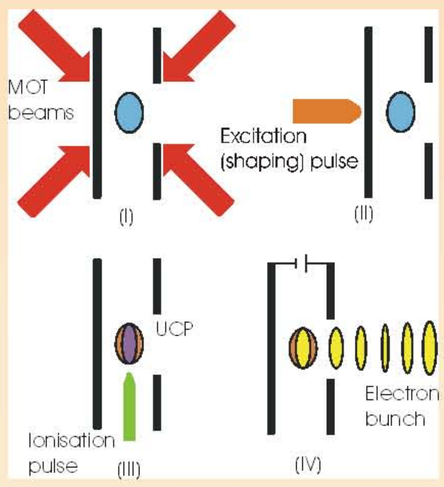
The quality of the beam is given by **brightness**.

Brightness: $B = \dfrac{I}{\epsilon_{n,x}\epsilon_{n,y}}$

Emittance: $\epsilon_{n,x} = \dfrac{1}{mc}\sqrt{< x^2 >< p_x^2 > - < xp_x >^2}$

I – peak current
ε - emittance
x – position
p_x – momentum

1. The Principle



(I) Rb Atoms trapped in a Magneto-Optical Trap (MOT)
5 x 10^9 atoms

(II) Excitation (shaping pulse)

$\rho(r) = \sqrt{1-(r/R)^2}$

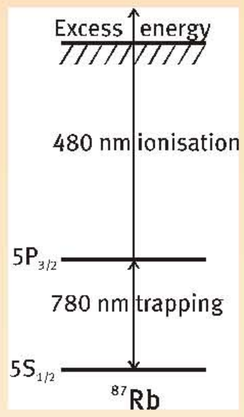
(III) Creation of UCP

At creation
Ion temperature 1mK
Electron temperature 100 mK

At extraction
Ion temperature 1 K
Electron temperature 10 K

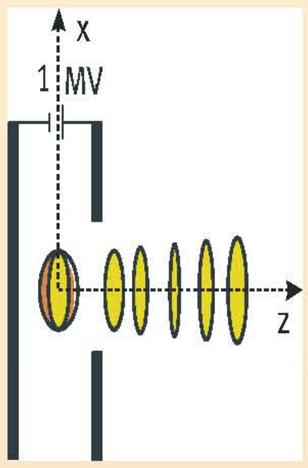
(IV) Extraction with an electric field of 1 MV with 150 ps rise time

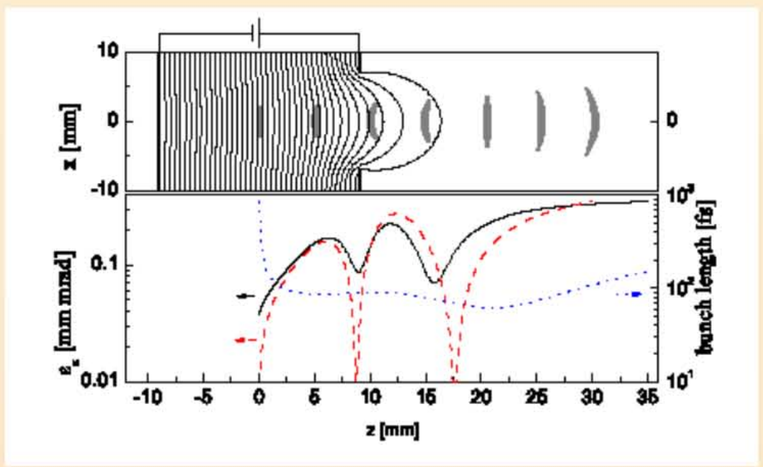
Procedure



2. The Pulsed DC Accelerator Design

Basic Design

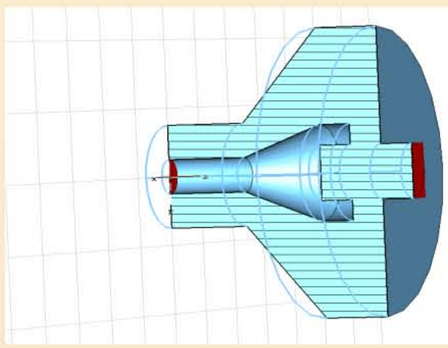


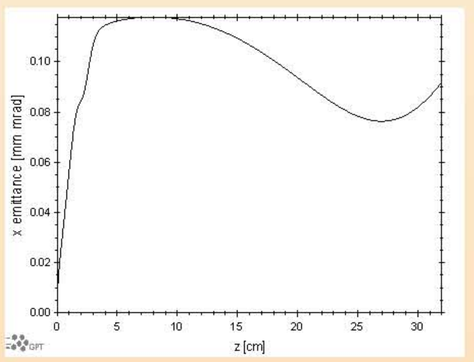


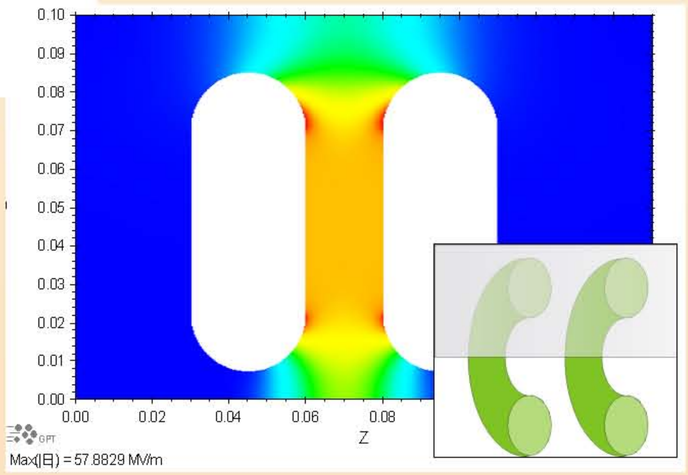
- Voltage: 1MV, 10 pC, 100 ps rise time
- Time focusing bunch length ‹ 1 ps
- Emittance at bunch minimum ‹ 0.1 mm mrad
- Brightness › 20 x 10^3 A/(mm mrad)^2 vs. 100 A/(mm mrad)^2

Simulation software

- General Particle Tracer (GPT)
- Superfish (SF)
- CST Microwave Studio



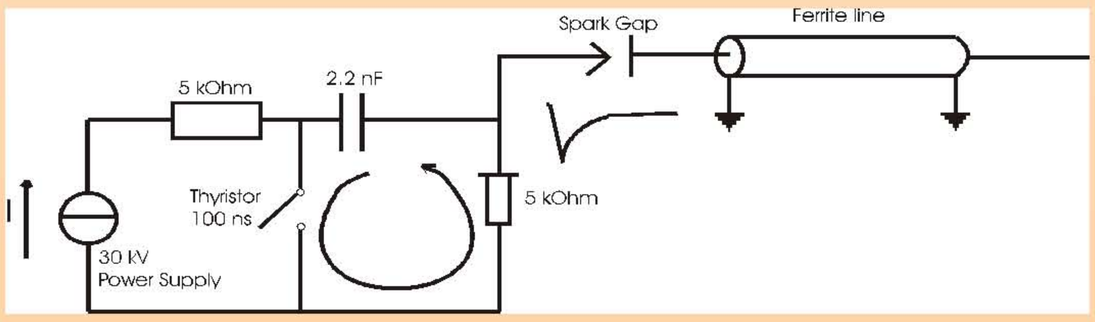


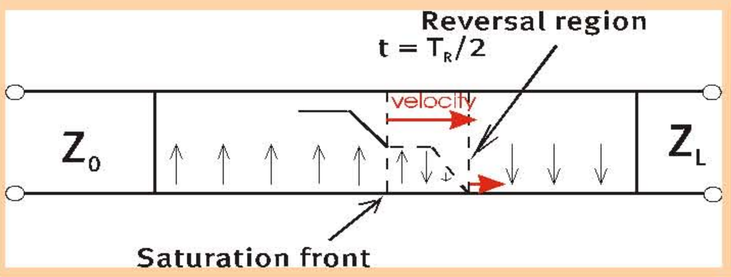


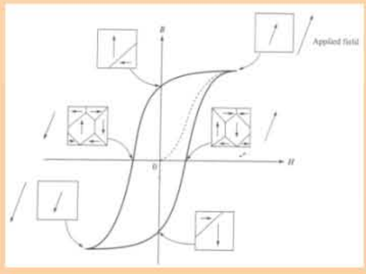
3. Fast Pulsed High Voltage Generation

Pulse Sharpening

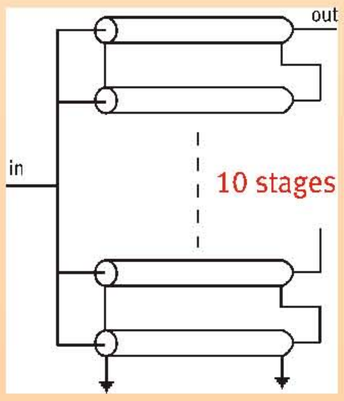
- Need of 1 MV pulses with 150 ps rise time;
- Make use of **ferrite line for pulse sharpening**:
  velocity ~ 1/permeability

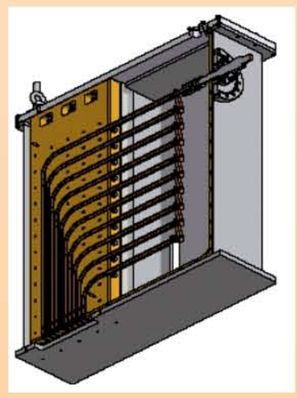






Transmission Line Transformer





The principle

- Amplification factor (ideal): 10.
- The Transmission Line Transformer is a fast transformer (sub-nanosecond) vs. Tesla coil transformer which is a slow transformer (microseconds).

The reality
Amplification factor (real): 7.5