DITANET SCHOOL
TRANSVERSE BEAM PROFILES EXERCISE

Beam parameters

$E_k := 3 \cdot 10^{6}$	eV
$I_{ave} := 40 \cdot 10^{-3}$	A
$t_{pulse} := 10 \cdot 10^{-6}$	s
$\sigma_s := 100 \cdot 10^{-12}$	s
$\sigma_x := 1.5 \cdot 10^{-3}$	m
$\sigma_y := 1.5 \cdot 10^{-3}$	m
$RF := 352 \cdot 10^{6}$	Hz

Grid parameters

$Y_{SEM} := 0.8$	From fig.1
$d_{wire} := 40 \cdot 10^{-6}$	m
$Z_{In} := 50$	Ω
$Gain := 100$	

Titanium parameters

$\rho_{Ti} := 4500$	Kg/m^3
$c_{p.Ti} := 540$	J/(Kg K)
$T_{m.Ti} := 1933$	K

Question 1

1MHz is much slower than the 352 MHz of the bunching frequency
we can thus consider the beam as continuous over the pulse length

The horizontal density of the beam current is given by

$$J_{LF}(x) := \frac{I_{ave}}{\sqrt{2\pi}\cdot\sigma_x}\cdot e^{\frac{-x^2}{2\cdot\sigma_x^2}}$$ A/m

and the current intercepted by a wire is (assuming the wire diametre << beam width)

$$I_{wire}(x) := J_{LF}(x)\cdot d_{wire}$$

$$I_{SEM}(x) := I_{wire}(x)\cdot 2\cdot Y_{SEM}$$ A — Current intercepted by a wire multiplied by twice the SEM yield as each particle will cross twice the surface (enter/exit)

$$V_{SEM}(x) := I_{SEM}(x)\cdot Z_{In}\cdot Gain$$ V — Signal induced in the readout electronics

$$I_{SEM}(0) = 6.809\times 10^{-4}$$ A

$$V_{SEM}(0) = 3.404$$ V

$$V_{SEM}\left(3\cdot 10^{-3}\right) = 0.461$$ V

Constant over the pulse length

Question 2

If the bandwidth is much broader than the RF, we must consider the fact that the beam
is bunched.

The charge of one bunch corresponds to the average current times the interval between two bunches

$$Q_{bunch} := I_{ave}\cdot\frac{1}{RF}$$ C

$$Q_{bunch} = 1.136\times 10^{-10}$$ C

Assuming t=0 at the beginning of the first bucket the beam current can be expressed as

$$I_{HF}(t) := \frac{Q_{bunch}}{\sqrt{2\pi}\cdot\sigma_s}\cdot e^{\frac{-\left(\mathrm{mod}\left(t,\frac{1}{RF}\right)-\frac{1}{2RF}\right)^2}{2\sigma_s{}^2}}$$ A

The mod is used to generate a repetitive gaussian with repetition rate 1/RF

$$J_{HF}(t,x) := \frac{I_{HF}(t)}{\sqrt{2\pi}\,\sigma_x}\cdot e^{\frac{-x^2}{2\sigma_x{}^2}}$$ A/m

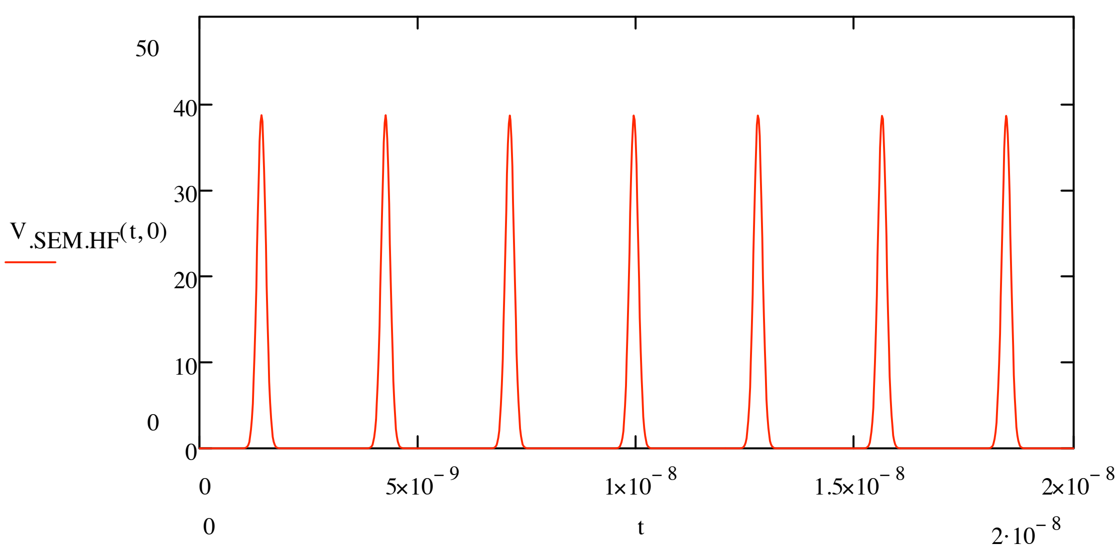
$$I_{SEM.HF}(t,x) := J_{HF}(t,x)\cdot d_{wire}\cdot 2\cdot Y_{SEM}$$ A

$$V_{SEM.HF}(t,x) := I_{SEM.HF}(t,x)\cdot Z_{In}\cdot \mathrm{Gain}$$ V

$$I_{SEM.HF}\left(\frac{1}{2RF},0\right) = 7.717\times 10^{-3}$$ A

$$V_{SEM.HF}\left(\frac{1}{2RF},0\right) = 38.583$$ V

$$V_{SEM.HF}\left(\frac{1}{2RF},3\cdot 10^{-3}\right) = 5.222$$ V



Question 3

We must first calculate the energy deposited by the beam

$$q_e := 1.602 \cdot 10^{-19}$$ C

From fig. 2 we have

$$dEdx := 75 \cdot 10^6 \cdot q_e \cdot \frac{1}{100^2} \cdot 1000$$ J m^2/Kg

The energy deposited in the infinitesimal element dV is

The transverse density of the particles, J, is given by

$$J_{tr}(x,y) := \frac{\frac{I_{ave}}{2\pi \cdot \sigma_x \cdot \sigma_y} \cdot e^{-\left(\frac{x^2}{2 \cdot \sigma_x^2} + \frac{y^2}{2\sigma_y^2}\right)}}{q_e}$$ e-/m^2

$$dE := dEdx \cdot \rho \cdot dz \cdot J \cdot dS \cdot t_{pulse}$$ $$dE := dEdx \cdot \rho \cdot J \cdot dV \cdot t_{pulse}$$

The temperature rise in the same volume element is

$$dT := \frac{dE}{c_p \cdot \rho \cdot dV}$$

From which

$$dT_{max}(\tau) := \frac{dEdx \cdot J_{tr}(0,0) \cdot \tau}{c_{p.Ti}}$$

$dT_{max}(t_{pulse}) = 392.975$ K This temperature rise is acceptable

Question 4

With a pulse of 25 μs the temperature rise is

$$dT_{max}\left(25\cdot 10^{-6}\right) = 982.438$$

at around 1000 C thermionic emission starts, the central wires that reach this high temperature will produce much larger signals as the thermionic emission adds to the secondary emission. As a consequence the profile looks narrower with large tails

At 45 μs the temperature rise is

$$dT_{max}\left(45\cdot 10^{-6}\right) = 1.768\times 10^{3}$$

The melting point of Titanium has been exceeded and the wires have been damaged