

PARTICLE-IN-CELL SIMULATIONS OF A VIRTUAL CATHODE OSCILLATOR WITH FEEDBACK MECHANISM

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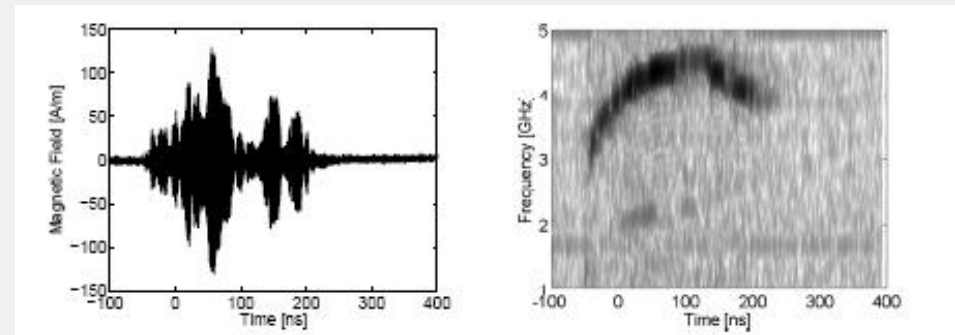
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- Viricator with feedback
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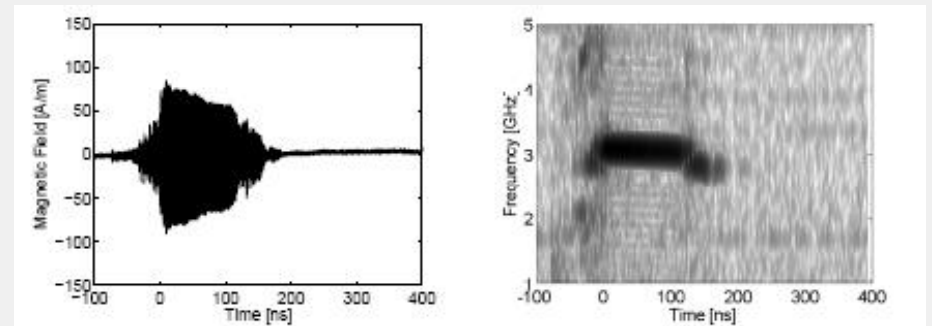
Background

- Vircators driven by non square pulse generators (such as a Marx generator) often exhibit frequency chirping
- Frequency chirping indicates poor interaction between the electron beam and the cavity and the result is usually low efficiency

Strong chirp



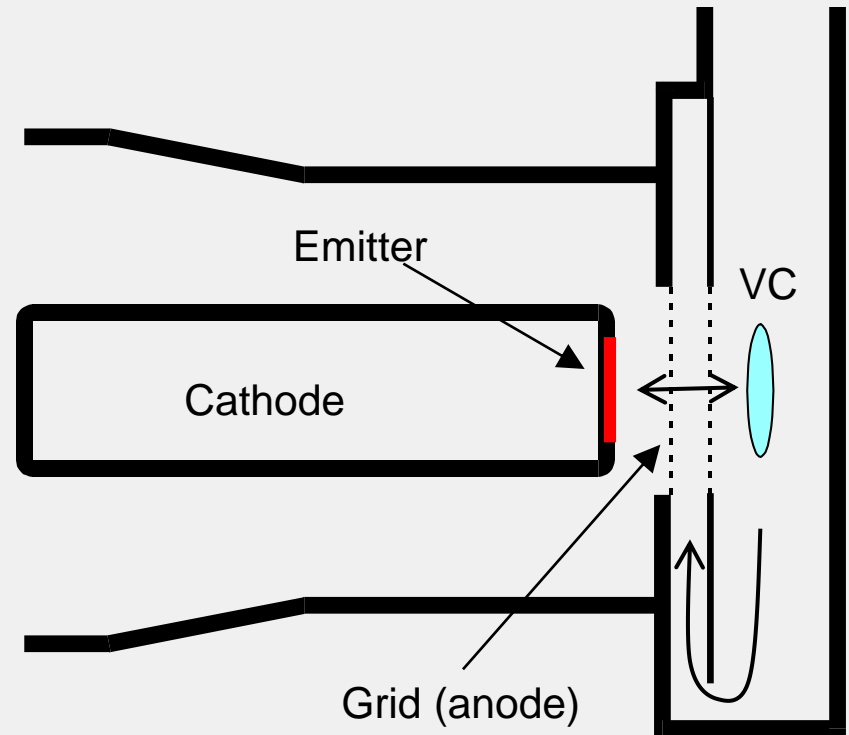
Limited chirp



Examples are from experiments with reflex triode

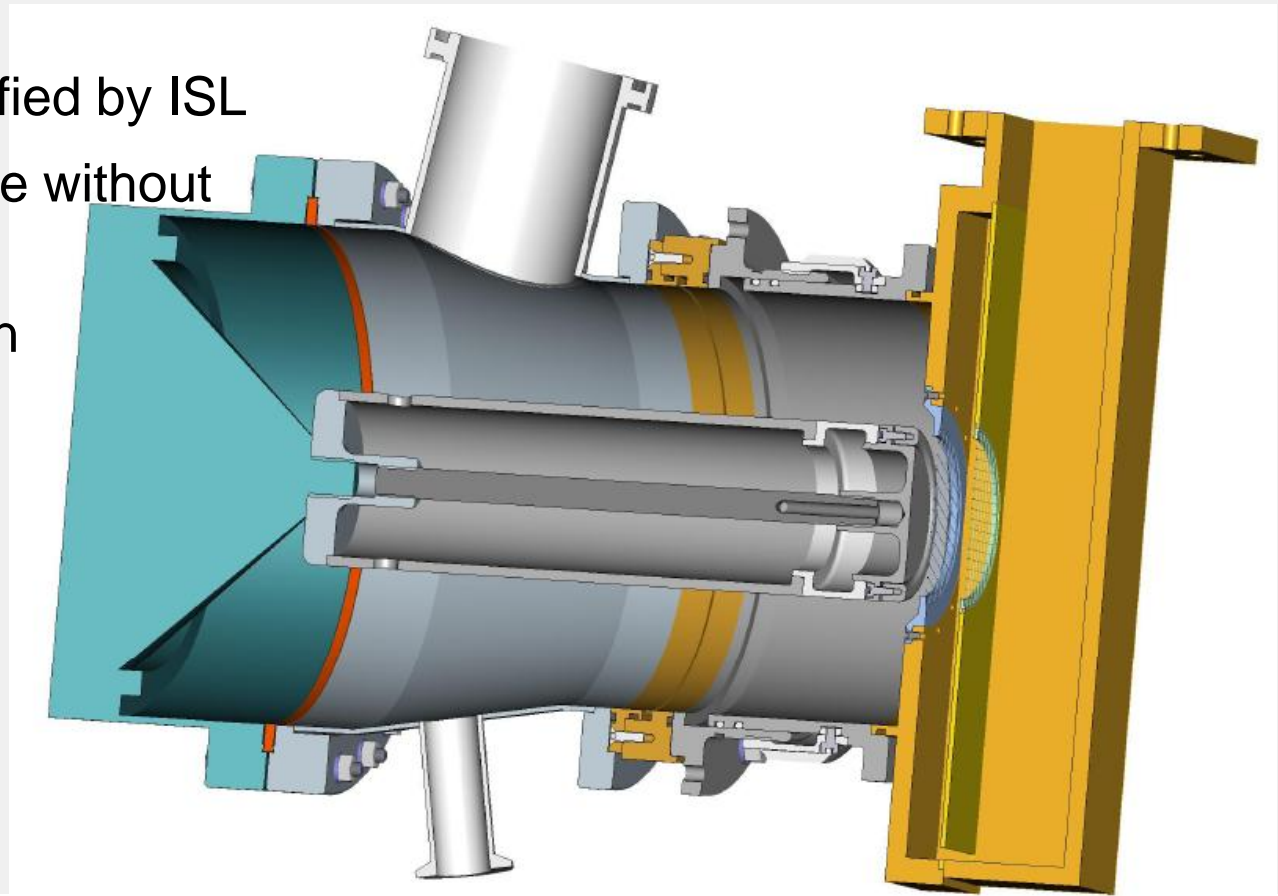
Background

- Want to avoid uncontrolled frequency chirping
- A vircator with feedback mechanism should be able to oscillate at stable frequency even if acceleration voltage changes during pulse

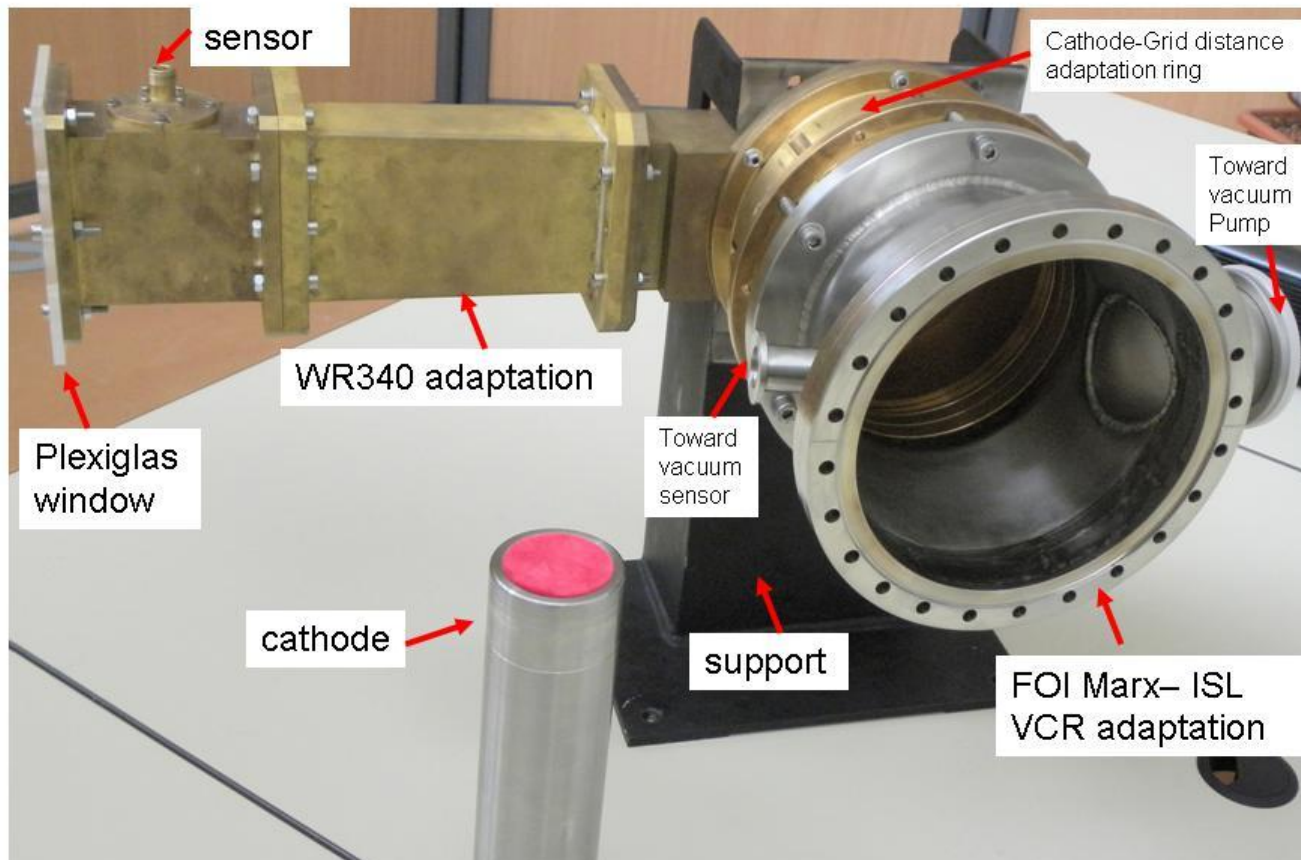


Vircator with feedback mechanism

- Built by Thales
- Owned and modified by ISL
- AK-gap adjustable without breaking vacuum
- 3D PIC simulation by FOI

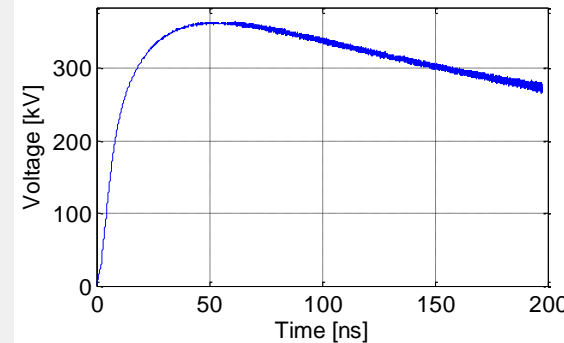


Viricator with feedback mechanism

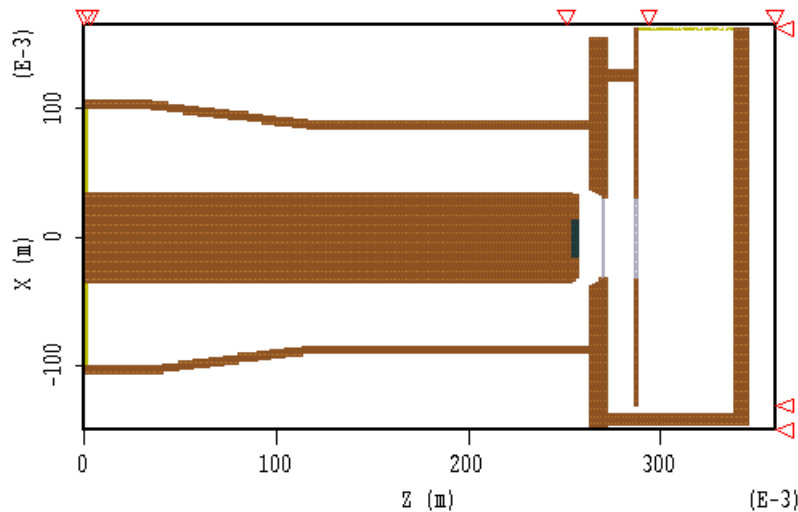


Simulation setup

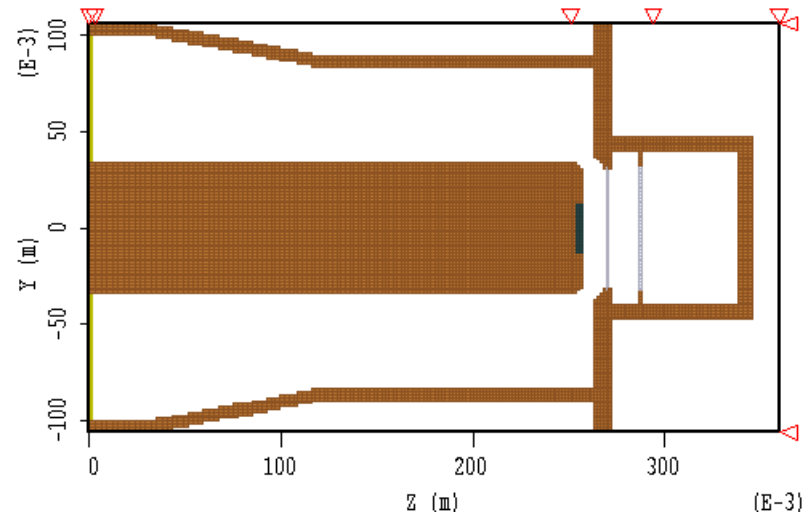
- Simulation set up in MAGIC 3D using Cartesian coordinates
- Vircator driven by voltage pulse adjusted to mimic pulse from (400 kV, 320J) Marx generator



Model of area X2 cross section



Model of area X1 cross section



Simulation setup

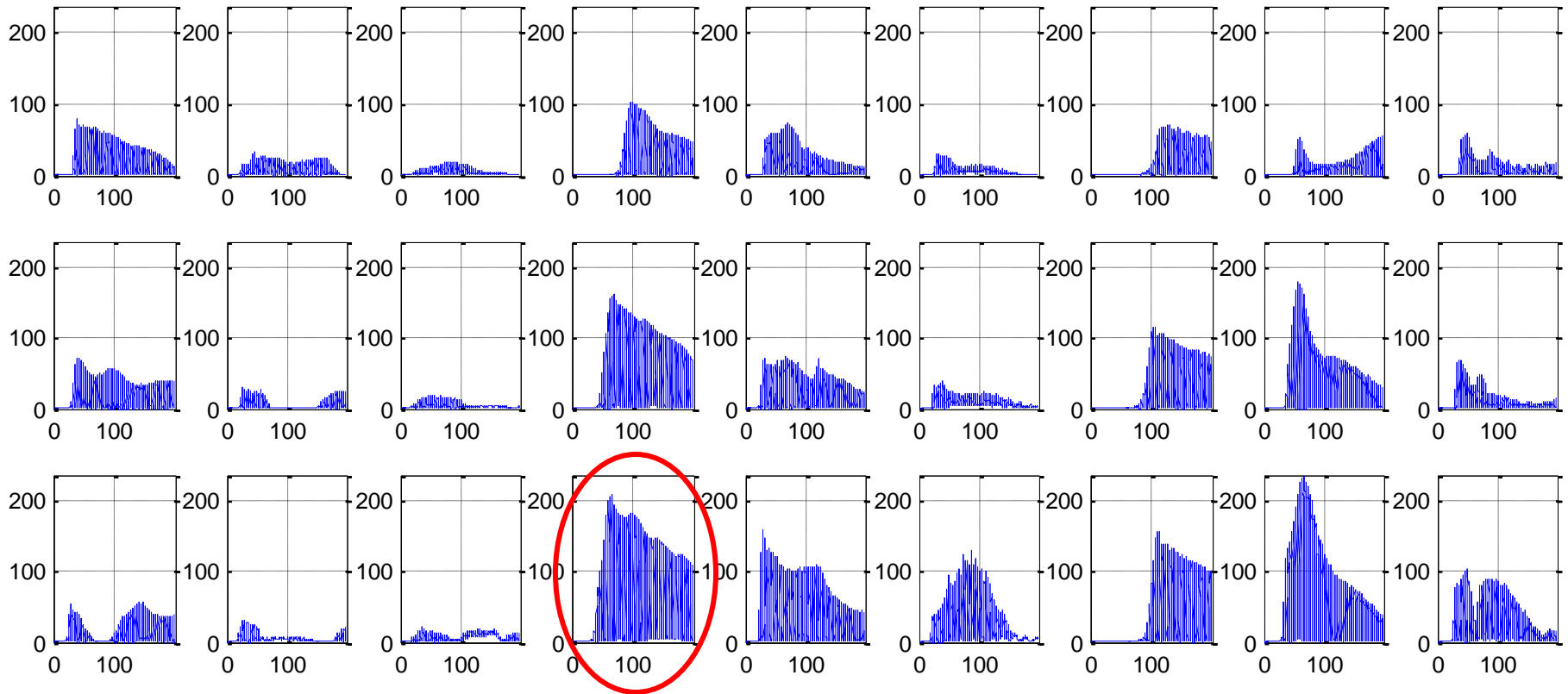
- Parametric study of applied voltage, AK-gap and emitter area

| Parameter | Value | Value | Value | Unit |
|----------------------|-------|-------|-------|------|
| U_{Marx} | 300 | 350 | 400 | kV |
| AK-gap | 10 | 12 | 14 | mm |
| R_{emitter} | 15 | 20 | 25 | mm |

- Parametric study consist of 27 simulations
- Simulations are run automatically using Matlab script

Simulation results

- Output power (MW) vs. Time (ns)

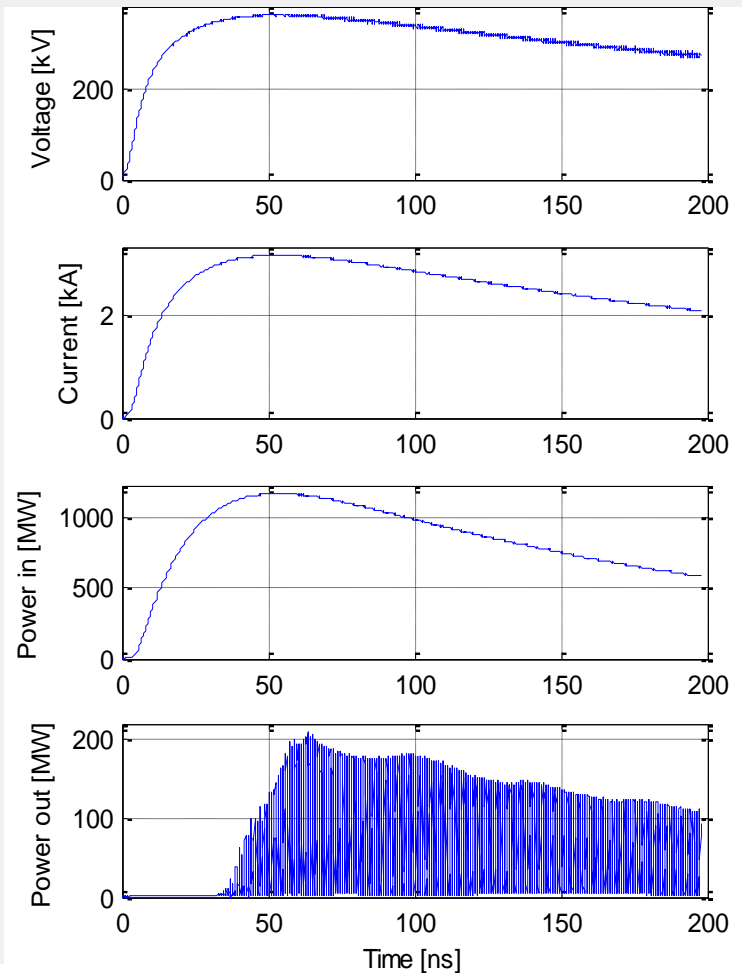


Best in terms of mean output power and energy efficiency



Simulation results

- Output data (27 sets) is processed to find simulation runs that exhibit the highest average output power and energy efficiency
- Best parameters found in first run was:
 - $U_{\text{Marx}} = 400 \text{ kV}$
 - AK-gap = 12 mm
 - $R_{\text{emitter}} = 15 \text{ mm}$
- Resulting output power and energy efficiency
 - $P_{\text{mean}} = 63 \text{ MW}$
 - $E_{\text{eff}} = 7 \%$



Simulation results

- Search the space close to 'best case'

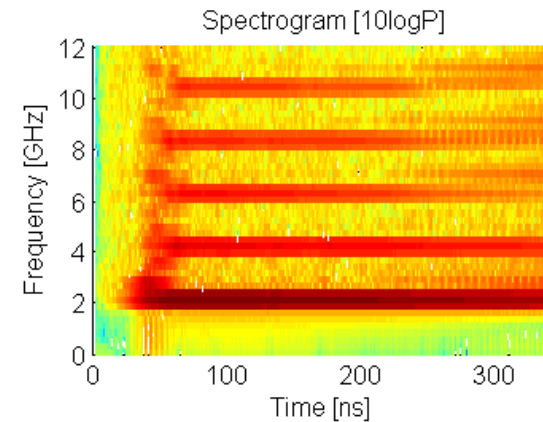
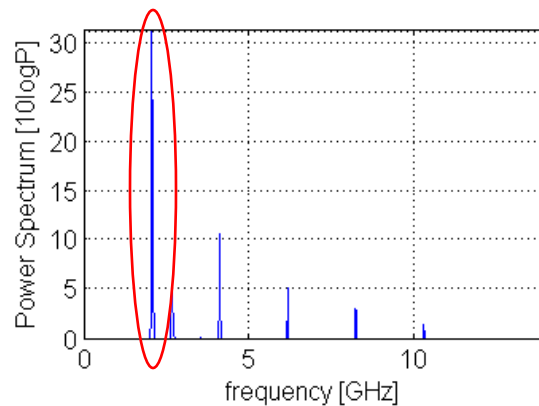
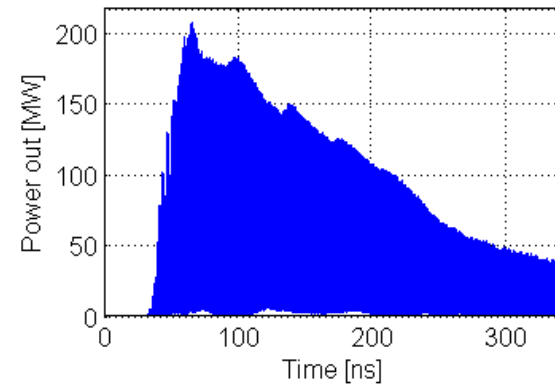
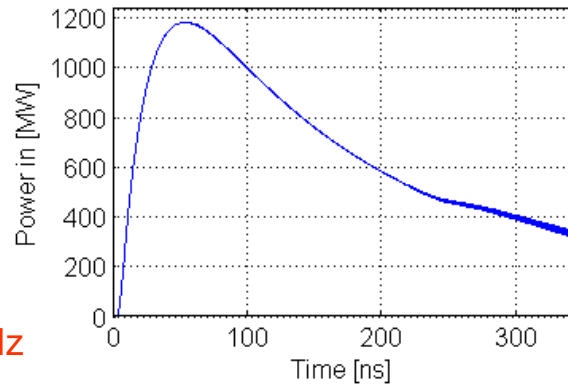
| U_{Marx} (kV) | AK (mm) | R_{emitt} (mm) | P_{mean} (MW) | E_{eff} (%) |
|------------------------|---------|-------------------------|------------------------|----------------------|
| 380 | 12 | 13 | 36 | 5.2 |
| 380 | 12 | 17 | 41 | 4.5 |
| 400 | 12 | 13 | 43 | 5.6 |
| 400 | 12 | 17 | 42 | 4.2 |

- Simulation using $U_{\text{Marx}}=400$ kV, AK-gap=12 mm, $R_{\text{emitter}}=15$ mm is still the best



Simulation check

- Check results by increasing number of particles and spatial resolution in a reference simulation for 'best case'



Frequency of fundamental is stable during entire pulse

Fundamental at 2 GHz
design frequency is
1.96 GHz
-> slight upshift due to
presence of electron
cloud



Conclusions and further work

- A parametric study of a vircator with feedback mechanism driven by a Marx generator was performed
- Charging voltage, AK-gap and emitter area was varied and an optimum configuration was found
- Simulations indicate that it is possible to drive the vircator with a non square pulse and still obtain a stable output frequency
- Energy efficiency $\sim 7\%$

- Experiments planned for beginning of 2011

