Using a traveling wave tube to analyze nonlinear effects in plasmas

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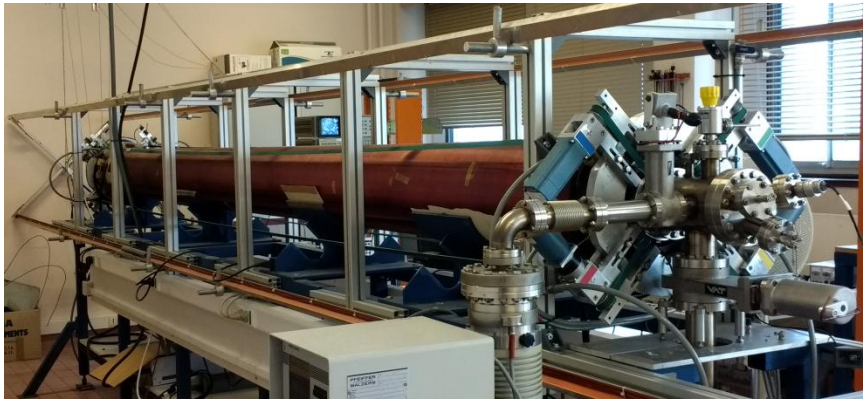
- 4 m long traveling wave tube (TWT) specially conceived for plasma physics research

  F. Doveil et al., Phys. Rev. Lett. 94, 085003 (2005)

- Electron beam interacts electromagnetic waves in vacuum:
  Experimentally mimic beam-plasma systems without background plasma effects
  Properly identify effects due beam dynamics

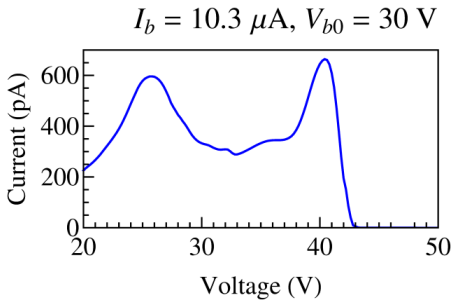
- Long enough: strong nonlinear effects after wave saturates

- Only TWT for plasma physics research currently in operation



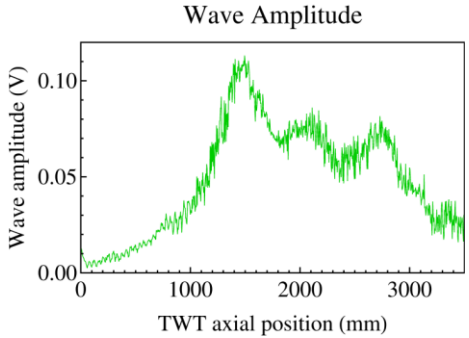
Beam-wave interaction: Nonlinear effects

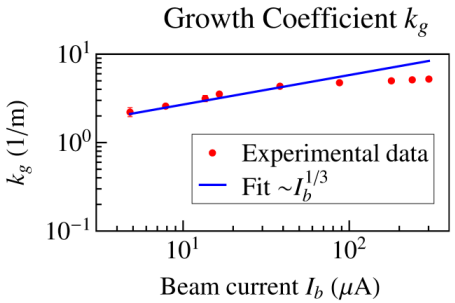
Beam modulation



- Initially monokinetic beam
- Initial velocity ($v_{b0} \rightarrow V_{b0}$ = 30 V) lower than phase velocity (v_ϕ)
- 2 peaks after interaction: V_b = 25.6 and 40.4 V ($\approx V_\phi$ for 15 MHz wave)

Wave growth and saturation (v_{b0} slightly higher v_ϕ)





- Wave receives momentum/energy from beam (<1500mm) Mechanism industrial TWTs used as signal amplifiers
- Nonlinear electron bunches after saturation (>1500mm) Trapped electrons move back and forth in wave potential
- Beam current $\gtrsim$ 100μA: nonlinear space charge effects, parameters deviate linear predictions

M. C. de Sousa *et al.*, *Phys. Plasmas* **27**, 093108 (2020)