Optical Stochastic Cooling for RHIC

Basic idea

Stochastic Cooling | **Optical Stochastic Cooling**

$N_s = \frac{\lambda}{3\Gamma}\frac{N_i}{\sigma_l}$ $\qquad n_d \approx 2eN_s$

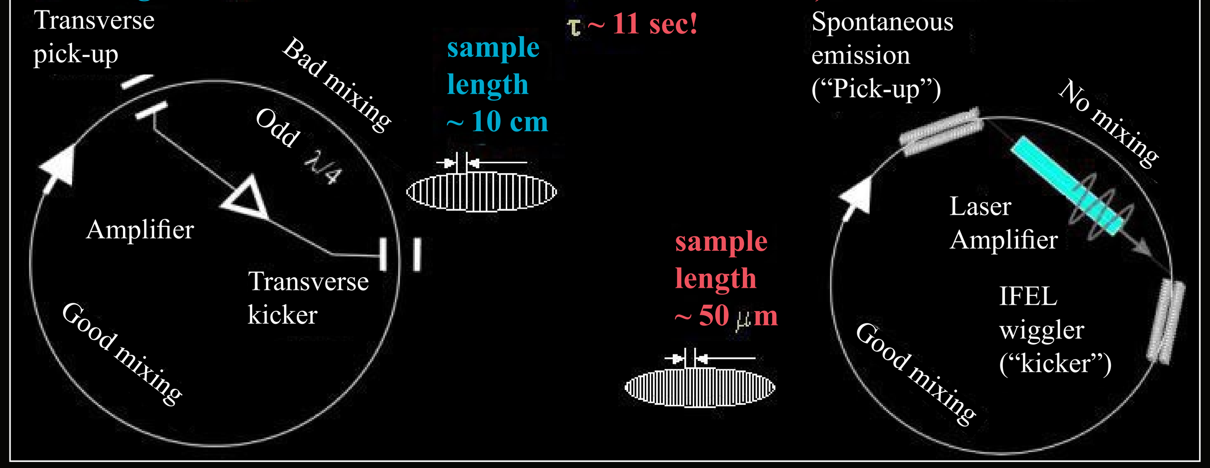
In practice $n_d = 20 n_d^{ideal}$ | **In practice time is amplifier limited**

λ~ 5 cm => ideal bandwidth limited cooling time τ ~2.5 hrs.

λ ~ 12 μm => power limited cooling time

τ ~ 1 hr. with 16 W; bandwidth limited

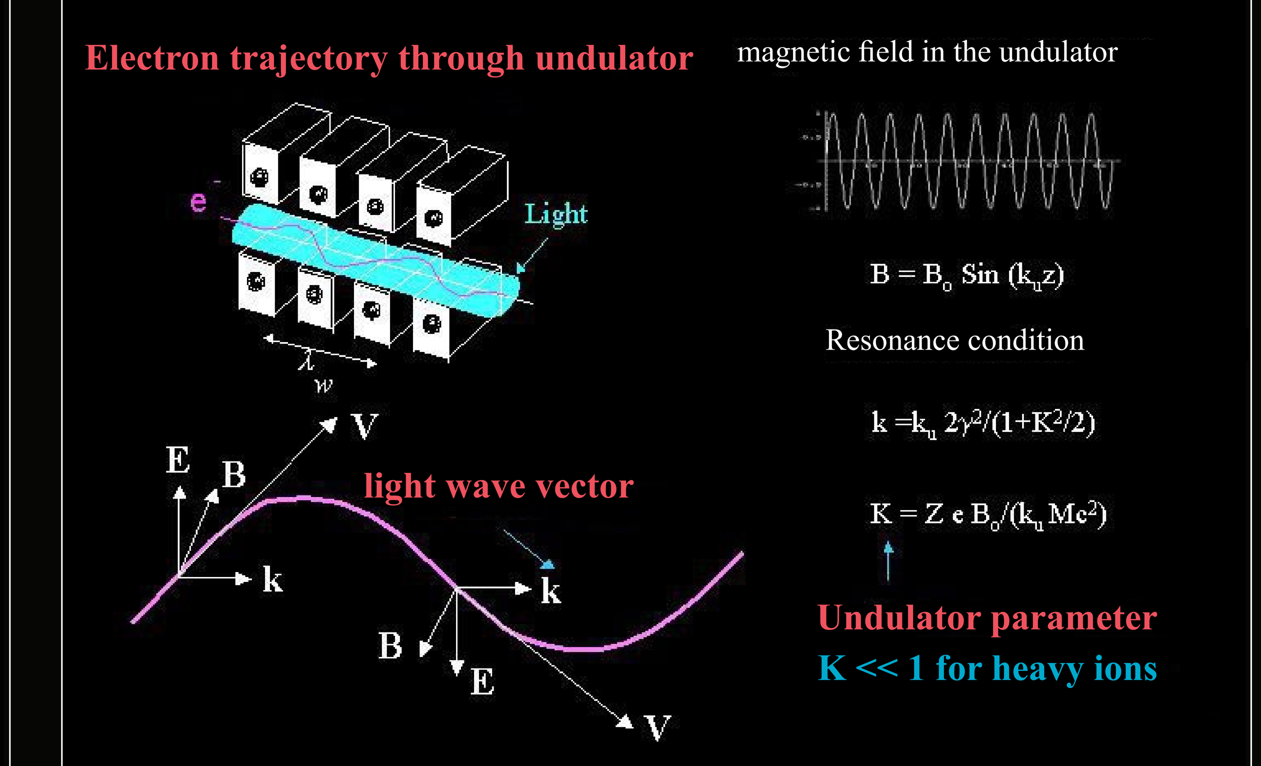
τ ~ 11 sec!



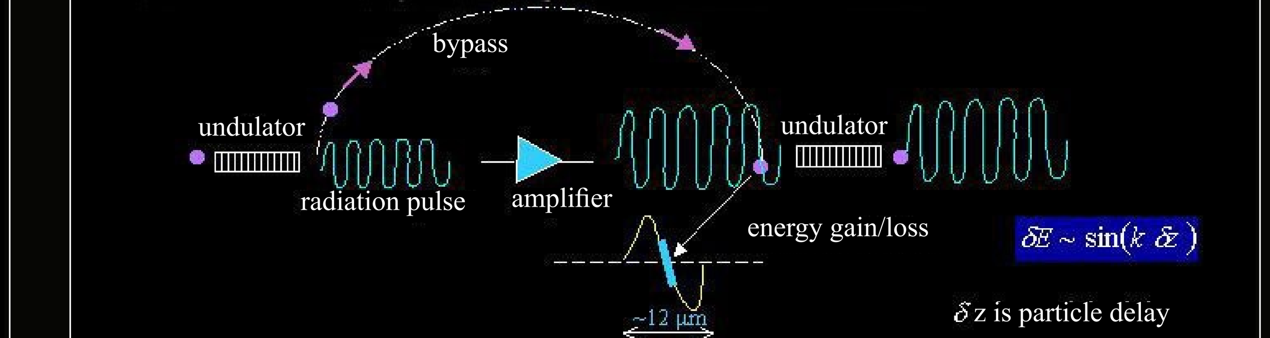
5 main components of OSC

- Optical amplifier (Optical Parametric Amplifier (OPA) : 3 cm long CdGeAs2 crystal, cooled to 77K for better thermal conductivity and transparency) (experimental tests within 1 year)
- Pump source for OPA (mode locked CO or CO-2 laser operating at 10 MHz with 200W output at 5.3 micron) (forgotten technology, design with 1 year)
- RHIC lattice modification design (exist only understanding what needs to be done)
- Diagnostics (needs to be developed)
- Pair (per ring) of 10T 3 meter long wiggler and modified RHIC bending magnets (to allow wiggler light extraction) (existing technology, need cost estimate)

Undulator can be used as the Pick up and Kicker



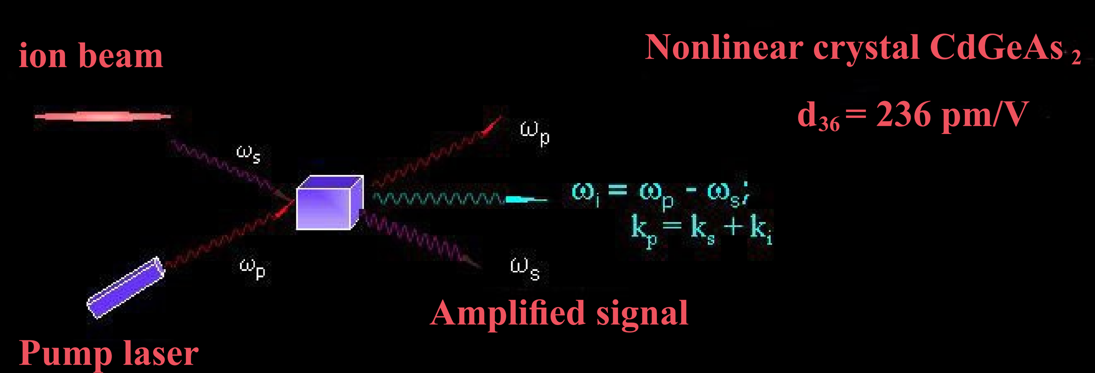
Transient Time Method of OSC



A pick-up and a kicker should be installed in a position with a nonzero dispersion function for a simultaneous cooling of energy and transverse coordinates *(similar to the Palmer's method of the momentum cooling).*

Coupling is used to share dumping between horizontal and vertical coordinates

Parametric Amplifier



λ_{pump} = 5.3 μm (Doubled frequency CO_2 laser)

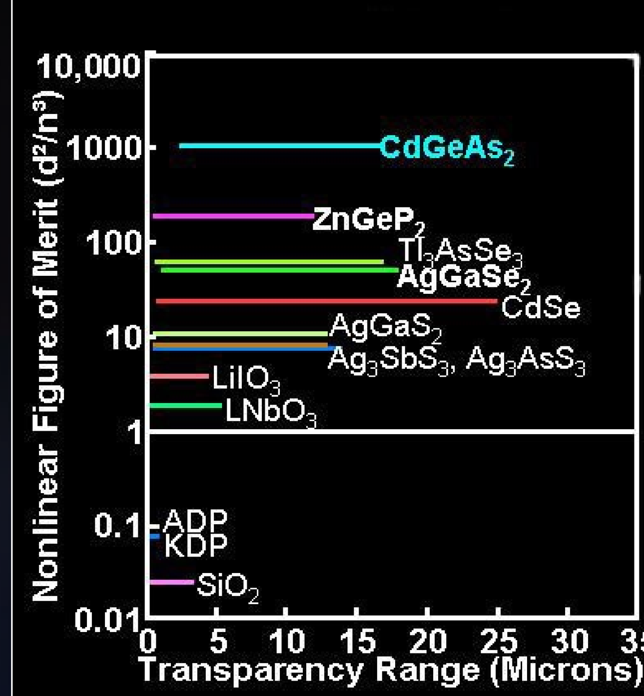
λ_{signal} = 12 μm

P_L = 20 MW/cm^2 (damage threshold, conservative)

1= 4 mm (*e* times gain length)

3 cm length crystal => intensity gain 3 10^5

$CdGeAs_2$ has long been known as a promising nonlinear optical material for IR frequency conversion



Advantages

- Highest Nonlinear Coefficient of any known compound (d_{14} =236 pm/V)
- Long Wavelength IR Cut-off (17 microns)
- Large Birefringence allows for Broad Phase-Matching range
- Adequate Thermal Conductivity (.042 W/cmK) for high power applications

Disadvantages

- Anisotropic Thermal Expansion (a-axis 15x> c-axis), cracking
- Defect-related Absorption Loss

Bypass for RHIC

RHIC parameters

Ions $^{+79}Au^{197}$ N_{ions}=120 x 1.2·10^9

E = 100 GeV/per nucleon

ε= 0.65·10^{-9} m σ_δ = 4·10^{-4}

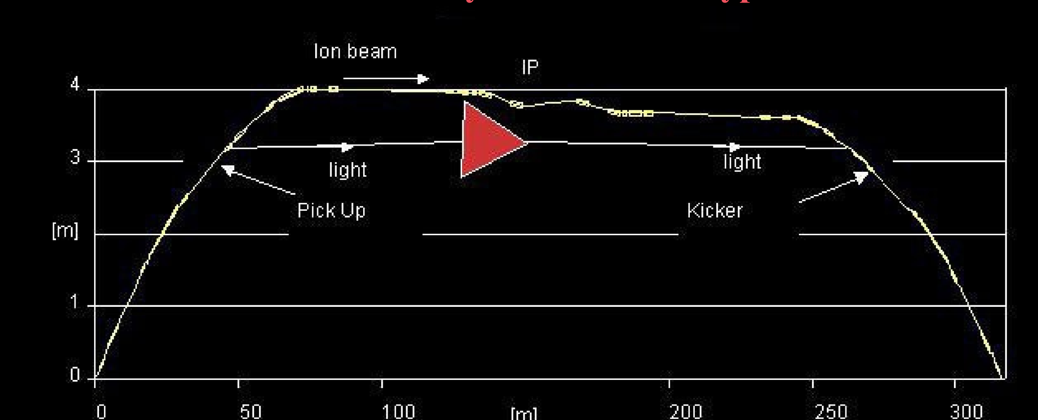
Perimeter = 3834 m.

Amplifier parameters

For 1 hour cooling time

λ= 12 μm required light power is P = 16 W

Preliminary schematic of bypass



Making sense of the different cooling techniques

Stochastic Cooling: beam error signal is measured by a pickup, amplified by RF amplifier and corrected in the kicker

- Experiment on RHIC-Spring 2004
- Works over wide range of ion beam energies
- Limited by amplifier bandwidth *~ 5GHz*
- Requires expensive RF amplifier
- *Possibly can cool only trails of the RHIC beam*

Optical SC: Same as SC, but at optical wavelength

- Not limited by amplifier bandwidth ~ 3 THz
- Can cool whole RHIC beam in one hour with 16W of optical power
- Favors large amplitudes, *can be adjusted for the different beam amplitudes*
- Greatly reduces requirements on electron current if used with EC
- Works over limited ~5-10% range of the ion beam energies
- Requires challenging RHIC lattice modifications
- *No experimental demonstration - period.*

Electron cooling: ion beam "heat" transferred to "cold" electron beam

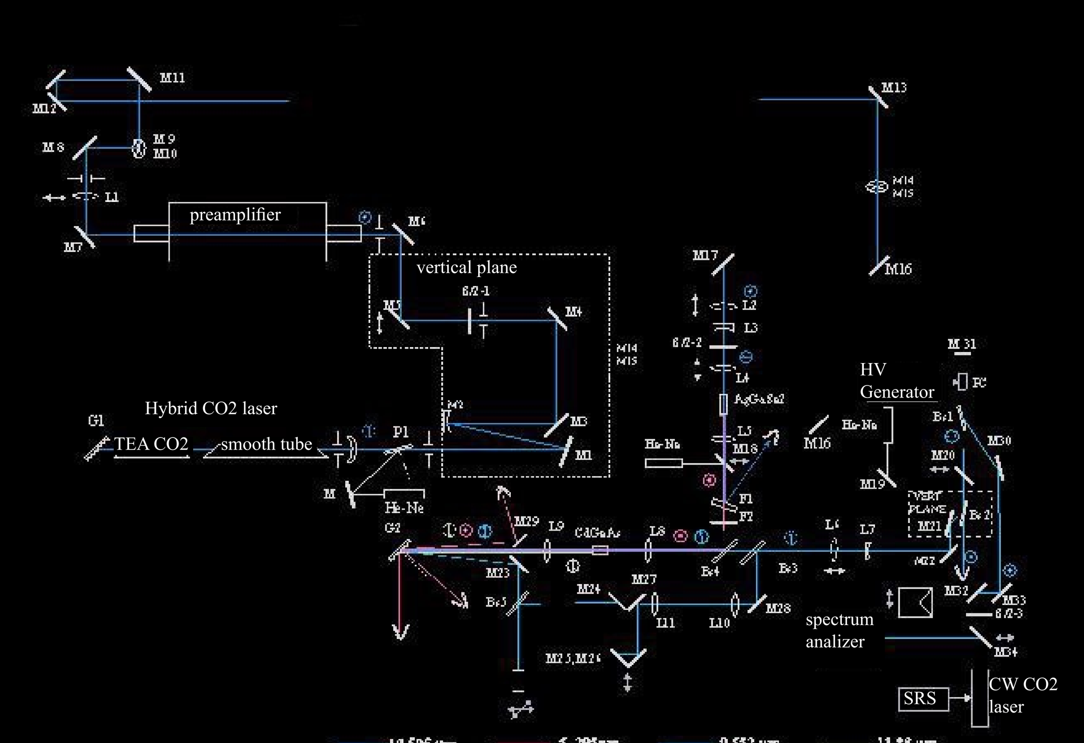
- Limited by electron beam current
- Works over wide range of the ion beam energies
- Effective for the beam core and against IBS (faster cooling for the colder beam)
- *Complimentary with OSC as it effective against IBS (main growth in RHIC)*

Requires *expensive and challenging* ERL and long solenoid

- *EC was not demonstrated at high energies*

Neither cooling was demonstrated for the bunched beam (Colors: Good, Bad)

Detailed plan of the test stand



OPA Test stand