Damping Ring Design and Physics Issues

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Purpose and Audience
The purpose of this course is to introduce the students to the design and physics issues of linear collider damping rings, with emphasis on beam dynamics. This course is suitable for anyone who has a basic understanding of the physics of electron storage rings, and who also has an interest in the specific challenges presented by damping rings.
Prerequisites: Basics of accelerator physics for electron storage rings.

Objectives
By the end of the course, students should be able to:
- describe the performance requirements of linear collider damping rings;
- explain the issues involved in optimization of values for the circumference, beam energy, and other parameters, and explain how the parameters for the ILC damping rings (for example) have been arrived at;
- explain the physics behind potentially limiting beam dynamics effects, including acceptance, vertical emittance, microwave instability, resistive-wall instability, intrabeam scattering, electron cloud effects and ion effects;
- perform initial assessments of the likely impact of certain potentially limiting effects, stating the relevant assumptions;
- describe the requirements for key technical subsystems, including the injection/extraction kickers, vacuum system, and the damping wigglers.

Instructional Method
There will be nine lectures over five mornings. Afternoon sessions will be used for both additional lectures and reviewing set problems. There will be homework and a final examination.

Course Content
The performance requirements of linear collider damping rings will be explored, and appropriate parameter regimes considered. Beam dynamics problems related to single-particle dynamics (dynamic aperture and acceptance, low-emittance tuning) and collective effects (microwave instability, resistive-wall instability, space-charge tune shifts, intrabeam scattering, electron cloud and ion effects) will be discussed. The requirements for some of the technical subsystems, including the injection/extraction kickers and the damping wigglers, will be considered in the context of present capabilities.

Credit Requirements
Students will be evaluated based on performance: final exam (50% of final grade), homework assignments (50% of final grade).

Outline of Lecture Contents

Lecture 1: Introduction to Damping Rings
- Role of the damping rings in a linear collider
- Principles of operation and overall structure
- Parameter and design constraints
- Injection and extraction

Lecture 2: Review of Linear Beam Dynamics and Radiation Damping
- Optical functions (beta function, dispersion)
- Momentum compaction
- Emittance, energy spread, bunch length
- Synchrotron radiation: energy loss and damping times
- Quantum excitation: equilibrium emittance, energy spread, bunch length

Lecture 3: Lattice Design
- Optical functions and lattice parameters as a function of cell design
- Lattice styles: FODO, DBA and TME lattices
- Chromaticity and chromatic correction
- Insertions: wiggler; injection/extraction

Lecture 4: Damping Wiggler and Nonlinear Dynamics
- Use of wigglers to enhance radiation damping
- Impact of wigglers on equilibrium beam sizes
- Nonlinear effects of wiggler fields
- Analysis methods for nonlinear dynamics

Lecture 5: Coupling and Alignment
- Fundamental lower limit on vertical emittance from synchrotron radiation
- Generation of vertical emittance from coupling and dispersion
- Coupling and dispersion generated by alignment errors
- Effects of magnet vibration
- Effects of ground motion

Lecture 6: Classical Coupled-Bunch Instabilities
- Wake fields and impedances
- Resistive-wall wake fields and higher-order modes
- Dynamics with long-range wake fields
- Resistive-wall instability growth rates
- Bunch-by-bunch feedback systems

Lecture 7: Space-charge, Intrabeam Scattering and Touschek Effects
- Space charge
- Intrabeam scattering
- Touschek effect

Lecture 8: Classical Single-Bunch Instabilities
- Short-range wakefields
- Potential-well distortion
- Microwave instability threshold
- Keil-Schnell-Boussard criterion
- Transverse mode coupling instability

Lecture 9: Ion Effects and Electron Cloud Effects
- Electron cloud effects
- Techniques for suppressing electron cloud
- Ion effects