PROJECT ADMINISTRATION DATA SHEET

[x] ORIGINAL [ ] REVISION NO. ______

Project No. G-41-651 (follow on to G-41-609) GTRI/GIT DATE 12/ 8 /83

Project Director: Dr. J. Ford School/Lab Physics

Sponsor: Dept. of Energy, Oak Ridge Operations, TN

Type Agreement: Mod. A003 to Contract DE-AS05-81ER40003

Award Period: From 12/1/83 To 11/30/84 (Performance) 11/30/84 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated:	$ 70,000	$ 70,000
Funded:	$ 70,000	$ 70,000

Cost Sharing Amount: $ None Cost Sharing No: N/A

Title: Dissipative Effects in the Beam-Beam Interaction of Intersecting Storage Rings

ADMINISTRATIVE DATA OCA Contact William F. Brown x4820

1) Sponsor Technical Contact:

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Ms. Joyce Carringer
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Defense Priority Rating: N/A

Military Security Classification: None

(or) Company/Industrial Proprietary: ---

RESTRICTIONS

See Attached Govt Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with GIT, if acquired by us and listed in Appendix "A"

COMMENTS:

Mod. A003 adds $70,000 as follow-on to G-41-609, new project number is required because of separate financial reporting requirements.

Total contract value (including previous project numbers) $249,000.

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FORM OCA 4:383

GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 8/2/85

Project No. G-41-651

School/Lab Physics

Includes Subproject No.(s)

Project Director(s) Dr. J. Ford

GTRC / GIT

Sponsor Department of Energy, Oak Ridge Operations, TN

Title Dissipative Effects in the Beam-Beam Interaction of Intersecting Storage Rings

Effective Completion Date: 11/30/84 (Performance) 11/30/84 (Reports)

Grant/Contract Closeout Actions Remaining:

- [X] None
- [ ] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. G-41-609

Continued by Project No. G-41-638

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diffusion is widely regarded as the potentially most dangerous weak instability in the beam-beam interaction.

The effects of dissipation due to synchrotron radiation are routinely included only in models of electron-positron machines; these effects have systematically been neglected in the case of heavy particles, e.g. p-p or p-$\bar{p}$, for which conservative (Hamiltonian) models have been uniformly employed. However in some recent experiments, the radiation emitted by proton beams has been detected and measured [9]. Moreover recent techonogical advances have achieved an exponential increase of the available center-of-mass energy [10]. These results make it quite clear that realistic models of heavy particle beam-beam machines must include the effect of a weak dissipation. The inclusion of radiation damping introduces a wide variety of new phenomena, such as adiabatic transport of particles in phase space, creation of attracting sets including "strange attractors" [11], random perturbations, etc. Finally it should be emphasized that the effects of small dissipation on weak instabilities are completely unknown. Thus, extensive studies of the cumulative effect of all these beam-beam phenomena seem to be in order, and even somewhat urgent, we would suggest.

In the following section, we discuss the work we have performed under previous award.

II. PROGRESS REPORT ON PREVIOUS AWARD : DE-AS05-81ER40003,A001

Our research has led to the following publications:

A F. Vivaldi and M. A. Lieberman, "Parametric Modulation in Nonlinear Oscillator Systems", in press.

B T. Bountis and F. Vivaldi, "Dynamics of Cylindrical Beams : The Symmetrical Case", preprint (1984).

C H. Hirooka, N. Saito, and J. Ford, "Chaos Around Hyperbolic Fixed Points", J. Phys. Soc. Japan, **53**, 985 (1984).

D G. Casati, J. Ford, F. Vivaldi, and W. M. Visscher, "One-Dimensional Classical Many-Body System Having a Normal Thermal Conductivity", Phys. Rev. Lett **52**, 1861 (1984).

E B. Eckhardt, J. Ford, and F. Vivaldi, "Analytically Solvable Systems Which Are Not Integrable", Physica D (1984) (to appear).

In Ref. A above we have extended our previous analytical treatment of the phenomenon of modulational diffusion [5,8,11], to include the case of small modulational frequency. The location and size of the stochastic domains, as well as the rate at which particles diffuse along them are determined analytically, as a function of the system parameters. Our technique is based on a resonant expansion of the Hamiltonian function, and it is therefore applicable to a large class of beam-beam models. With these tools conditions for beam stability can be formulated without the need for direct numerical simulations. The destabilizing effect of tune modulation is found to be present in a broader range of parameters than previously conjectured [5]. Moreover, at selected values of the betatron amplitudes, (which constitute a Cantor set in phase space), the diffusion coefficient is discovered to increase indefinitely with time, posing an additional threat to particles' stability. This phenomenon, which originates from the power-law decay of correlations in the stochastic domains [17], is found to be attenuated, but not eliminated, by a weak dissipation. The transition to Arnol'd diffusion is studied in detail. This investigation will be published shortly.

In Ref. B, we have considered the stability problem for a family of models of cylindrically symmetrical beams, in presence of moderate dissipation. A general method for the reduction of this problem to the study of a map of the plane into itself is developed, which is based on the existence of a global invariant of the motion. Conditions for beam stability for all time are then derived. The theory of adiabatic invariants is then used to predict location of the various attracting sets in phase space and the size of the corresponding basins of attraction.

In ref. C the nature of particle motions in the vicinity of nonlinear resonances is examined in detail. A simple mechanism yielding chaotic motion and unpredictability is illustrated.

In Ref. D the problem of determining transport coefficients for many-particle chaotic systems is studied. A numerical technique is presented, which provides accurate estimates with relatively short computation times.