



**The Abdus Salam
International Centre for Theoretical Physics**



2286-7

Workshop on New Materials for Renewable Energy

31 October - 11 November 201

Solitons: the history and some recent advances

Yuri S. Kivshar

*Nonlinear Physics Centre
Research School of Physics and Engineering
The Australian National University
Canberra ACT 0200
Australia*

Solitons: the history and some recent advances

Yuri Kivshar

**Nonlinear Physics Centre
Research School of Physics and Engineering
Australian National University**



Nonlinear Physics Center

1993

**Nonlinear photonics
& solitons: theory**

(Dr. A. Sukhorukov)

**Nonlinear photonics:
experimental**

**(Dr. D. Neshev
NLPC Deputy Head)**

October 2011

16 research fellows

4 visitors

12 PhD students



**Metamaterials
(Dr. I. Shadrivov)**

Nonlinear matter waves

(Dr. E. Ostrovskaya)

**Singular light &
optical vortices**

(Dr. A. Desyatnikov)

**Plasmonics and
nanoantennas**

(Dr. A. Miroshnichenko)

Nonlinear Physics Center: 2001-2011

WEB OF KNOWLEDGESM

DISCOVERY STARTS HERE

THOMSON REUTERS

[Sign In](#) | [Marked List \(0\)](#) | [My EndNote Web](#) | [My ResearcherID](#) | [My Citation Alerts](#) | [My Journal List](#) | [My Saved Searches](#) | [Log Out](#) | [Help](#)

[All Databases](#) | [Select a Database](#) | [Web of Science](#) | [Additional Resources](#)

[Search](#) | [Author Finder](#) | [Cited Reference Search](#) | [Structure Search](#) | [Advanced Search](#) | [Search History](#)

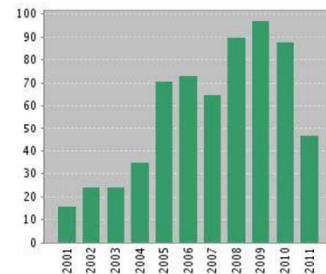
Web of ScienceSM

[<< Back to previous results list](#)

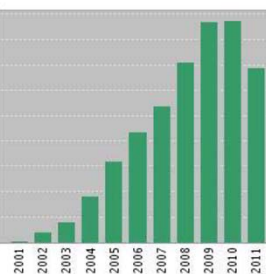
Citation Report Address=(nonlinear) AND Address=(canberra)
Timespan=2001-2011. Databases=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH.

This report reflects citations to source items indexed within Web of Science. Perform a Cited Reference Search to include citations to items not indexed within Web of Science.

Published Items in Each Year



Citations in Each Year



Results found: 630

Sum of the Times Cited [?]: 9500

Sum of Times Cited without self-citations [?]: 7951

Citing Articles [?]: 4890

[View Citing Articles](#)

[View without self-citations](#)

Average Citations per Item [?]: 15.08

h-index [?]: 46

Results: 630

Page 1 of 63

Sort by: Times Cited -- highest to lowest



Use the checkboxes to remove individual items from this Citation Report or restrict to items published between 2001 and 2011



1. Title: [Nonlinear properties of left-handed metamaterials](#)
Author(s): Zharov AA; Shadrivov IV; Kivshar YS
Source: PHYSICAL REVIEW LETTERS Volume: 91 Issue: 3 Article Number: 037401 DOI: 10.1103/PhysRevLett.91.037401 Published: JUL 18 2003



2. Title: [Spatial solitons in optically induced gratings](#)
Author(s): Neshev D; Ostrovskaya E; Kivshar Y; et al.
Source: OPTICS LETTERS Volume: 28 Issue: 9 Pages: 710-712 DOI: 10.1364/OL.28.000710 Published: MAY 1 2003



3. Title: [Observation of discrete vortex solitons in optically induced photonic lattices](#)
Author(s): Neshev DN; Alexander TJ; Ostrovskaya EA; et al.
Source: PHYSICAL REVIEW LETTERS Volume: 92 Issue: 12 Article Number: 123903 DOI: 10.1103/PhysRevLett.92.123903 Published: MAR 26 2004

	2007	2008	2009	2010	2011	Total	Average Citations per Year
	1076	1421	1743	1747	1380	9500	863.64
1.	31	38	33	40	28	233	25.89
2.	28	30	14	16	14	225	25.00
3.	27	30	37	25	18	219	27.38

Outline of today's talk

From the history of solitons

- Fermi-Ulam-Pasta problem
- Frenkel-Kontorova model and SG equation

Some recent advances

- Optical solitons in periodic structures
- Surface solitons
- Polychromatic solitons
- Self-trapped localized states

What is “soliton” ?



NAVIGATION
+ WHAT IS SOLITONCITY?
+ REGISTRATION
+ PRACTITIONERS
+ SCHEDULE
+ HOTELS
+ DI
+ AE
+ EM
+ CC



[site map](#) | [web confe](#)

[HOME](#) | [ABOUT US](#) | [SOLUTIONS](#) | [SERVICES](#) | [NEWS & EVENTS](#)

CON
THE
83 S
VENI
PH: I
FX: I
info



TimeSquare is a



Site search

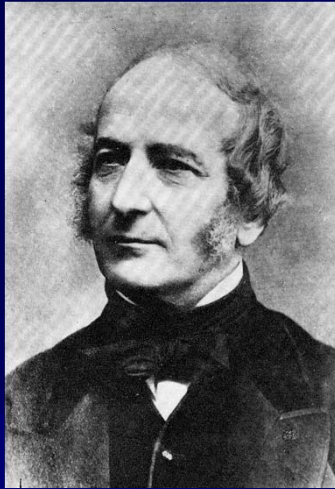


A new wave of excellence

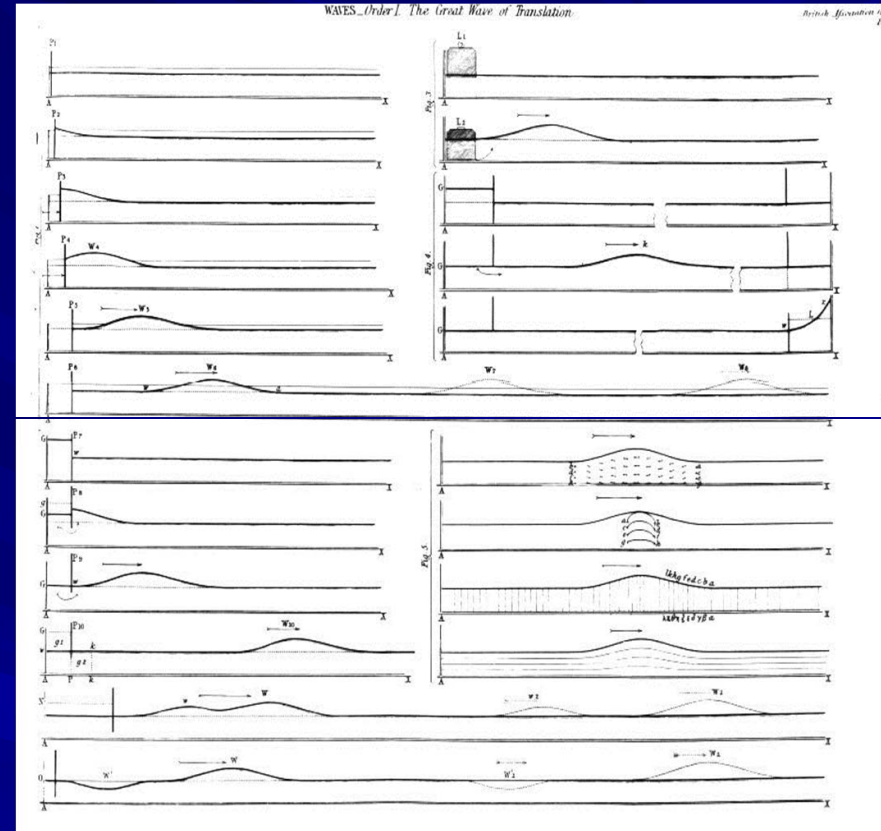
Soliton is a technology company with operations in India and the US serving companies such as GE, IBM, Ford, and Nortel.

The company has distinguished itself by winning 23 international awards for innovations so far and takes great pride in its reputation for outstanding customer service.

John Scott Russell (1808-1882)

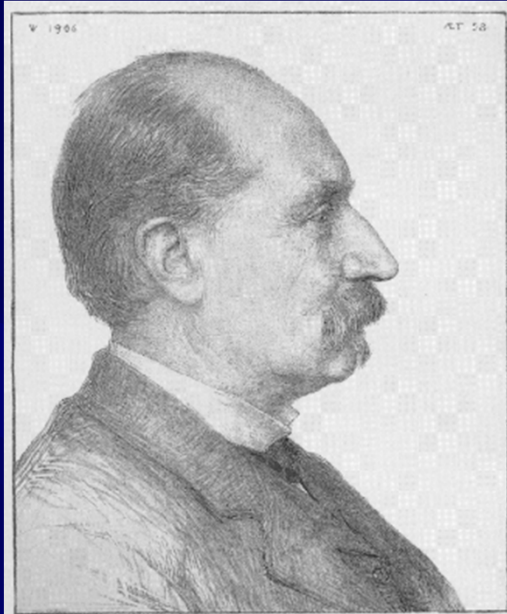


Very bright engineer: invented an improved *steam-driven road carriage* in 1833. "Union Canal Society" of Edinburgh asked him to set up a navigation system with steam boats



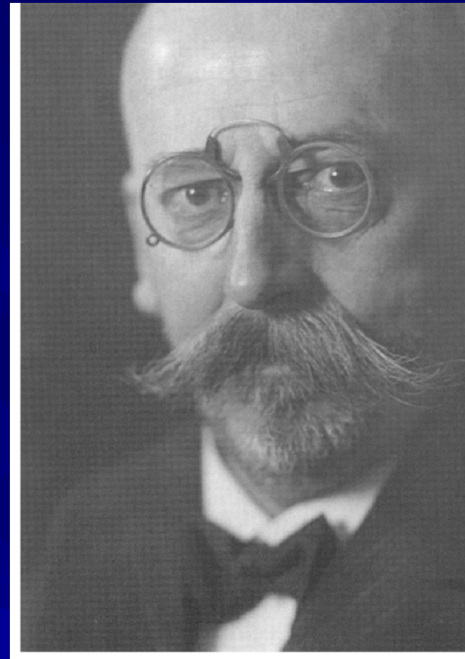
During his investigations, 6 miles from the centre of Edinburgh, he observed a *soliton* for the first time in August 1834

Korteweg-de Vries equation



Diederik Johannes Korteweg
(1848-1941)

$$\frac{\partial w}{\partial t} + \frac{\partial^3 w}{\partial x^3} - 6w \frac{\partial w}{\partial x} = 0$$



Gustav de Vries
(1866-1934)

D.J. Korteweg & F. de Vries,
Phil. Magazine 39, 422 (1895)

Fermi, Pasta, and Ulam



Fermi-Pasta-Ulam Problem

851

LOS ALAMOS SCIENTIFIC LABORATORY
of the
UNIVERSITY OF CALIFORNIA

Report written:
May 1955

Report distributed: November 2, 1955

LA-1940

STUDIES OF NONLINEAR PROBLEMS. I

Work done by:

E. Fermi
J. Pasta
S. Ulam
M. Tsingou

Report written by:

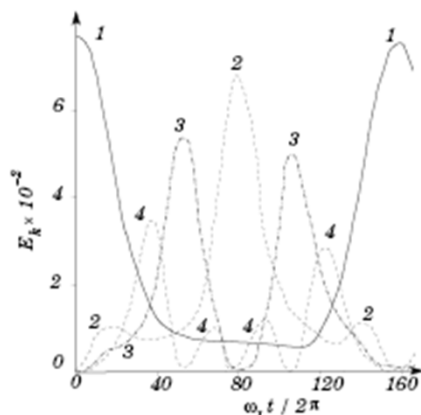
E. Fermi
J. Pasta
S. Ulam

PHYSICS

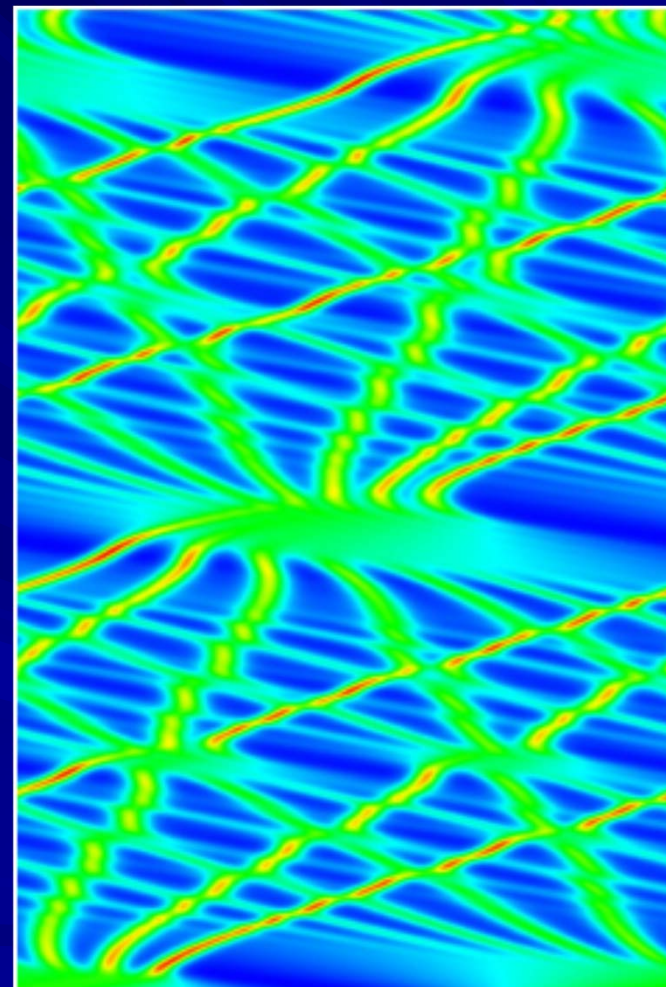
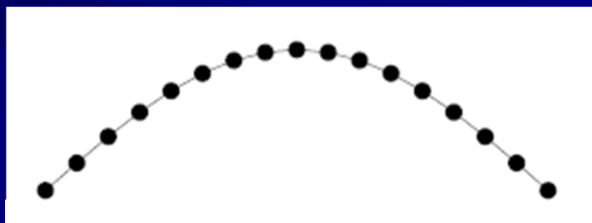
FPU problem

The first ever numerical experiment
(Los Alamos 1955)

$$H = \sum_{i=0}^N \frac{1}{2} p_i^2 + \sum_{i=0}^N \frac{1}{2} (u_{i+1} - u_i)^2 + \frac{\alpha}{3} (u_{i+1} - u_i)^3$$



Initial condition



Zabusky, 1977

“Solitons”

VOLUME 15, NUMBER 6

PHYSICAL REVIEW LETTERS

9 AUGUST 1965

INTERACTION OF “SOLITONS” IN A COLLISIONLESS PLASMA AND THE RECURRENCE OF INITIAL STATES

N. J. Zabusky

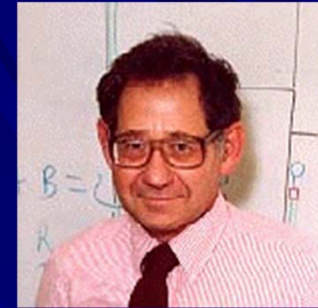
Bell Telephone Laboratories, Whippany, New Jersey

and

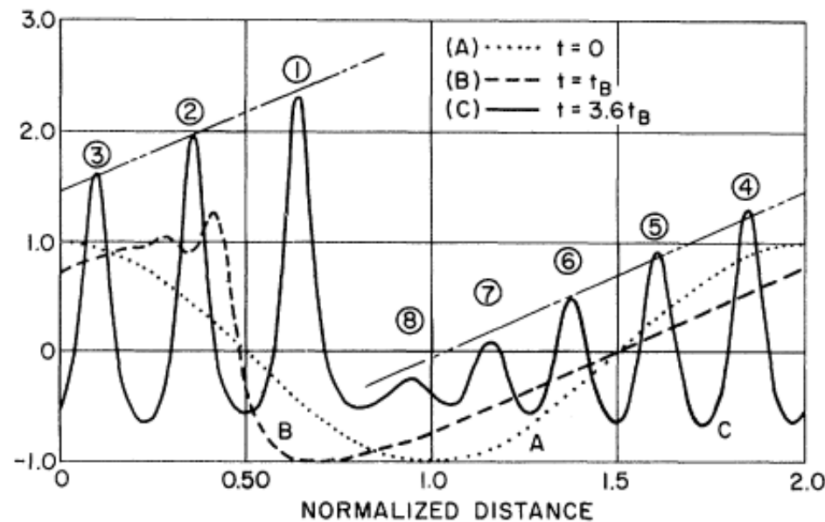
M. D. Kruskal

Princeton University Plasma Physics Laboratory, Princeton, New Jersey

(Received 3 May 1965)



(1925-2006)



⁵E. Fermi, J. R. Pasta, and S. Ulam, Los Alamos Scientific Laboratory Report No. LA-1940, May 1955 (unpublished). See reference 3 for a review of the problem.

1390 citations (ISI: Nov 2011)

25th
Annual
CNLS
International
Conference

MAY 16-20, 2005 • RADISSON SANTA FE
Santa Fe, New Mexico

**50 Years of the
Fermi-Pasta-Ulam Problem:
Legacy, Impact, and Beyond**

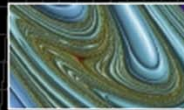
Featured Speakers
(a partial listing):

R. Austin, Princeton
A. Bishop, LANL
R. Camassa, N. Carolina
D. Campbell, BU
T. Dauxois, Lyon
C. Ellerbe, Edinburgh
M. Feigenbaum,
Rockefeller
S. Flach, Dresden
I. Galkov, Arizona
A. Garcia, RPI
Y. Kivshar, Canberra
S. Maunula, Arizona
L. Molleaves, Lucent
K. Rasmussen, LANL
M. Schick, Washington
H. Segur, Colorado
A. Shure, LANL
A. Slevin, Cornell
A. Ustinov, Erlangen
M. Wadati, Tokyo
G. Zaslavsky, NYU
G. Zocchi, UCLA

$$V(x) = \frac{1}{2}Kx^2 + \frac{\alpha}{3}x^3 + \frac{\beta}{4}x^4$$



Enrico Fermi,
Stanislaw Ulam, and
John Pasta (from left)



May 2005 marks 50 years of the seminal paper by Enrico Fermi, John Pasta, and Stanislaw Ulam simulating a mass-nonlinear spring chain. This discovery evolved into a whole new era of nonlinear science including localized excitations in many fields of physics: intrinsic localized modes and breathers in low-dimensional materials and nonlinear lattices, optical transmission, Bose-Einstein condensates, biophysics.

In addition, during this conference we will celebrate 25 years of the Center for Nonlinear Studies (CNLS) which cradled and incubated many new ideas in nonlinear science including chaos, turbulence, finance, networks, and solitons.

CONFERENCE ORGANIZERS

Alan Bishop, LANL
David Campbell, Boston Univ.
Robert Ecke, LANL
Avadh Saxena, LANL

CONFERENCE COORDINATION

Roderick Garcia, LANL
Phone: (505) 664-0188
Fax: (505) 665-2659
Email: rgarcia@lanl.gov

ONLINE INFORMATION <http://cnls.lanl.gov/Conferences/annual25/>

LALP-05-011

*LANL - Los Alamos National Laboratory

The World's Greatest Science
Protecting America

Los Alamos
NATIONAL LABORATORY
SERVING



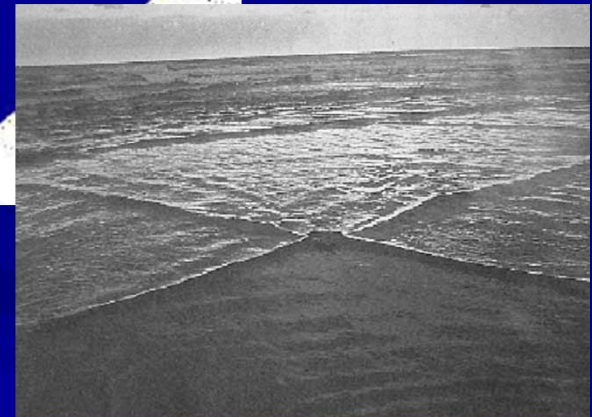
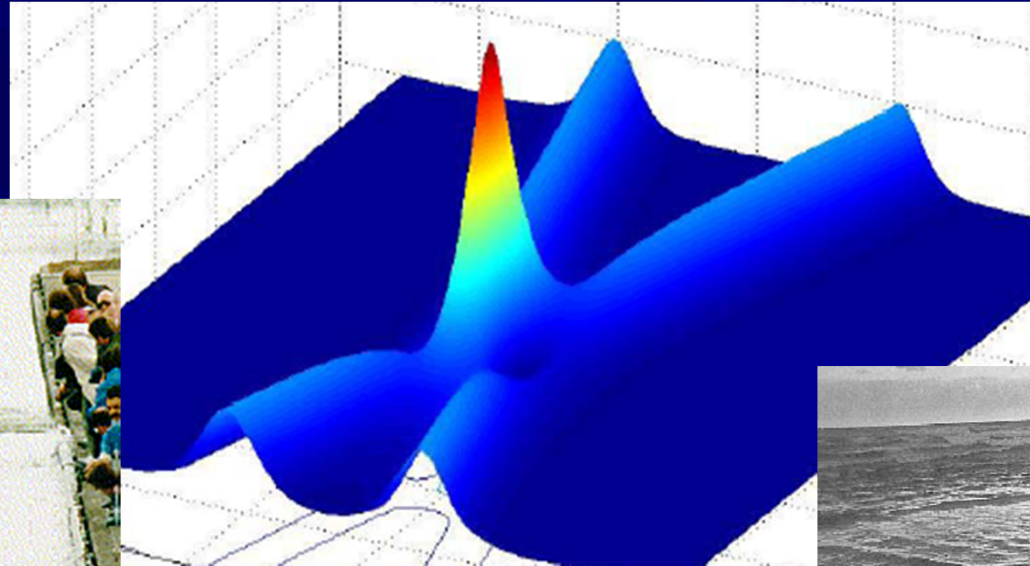
**May 16-20, 2005
Santa Fe, NW (USA)**



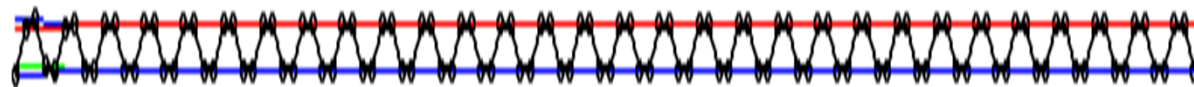
Los Alamos and CNLS, May 1990



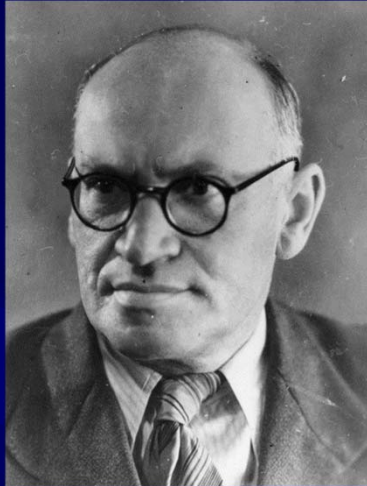
Solitons



Nonlinear localized waves existing when nonlinearity is balanced by dispersion



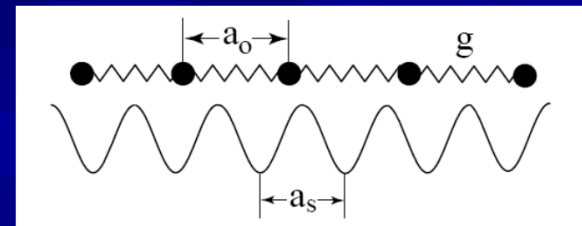
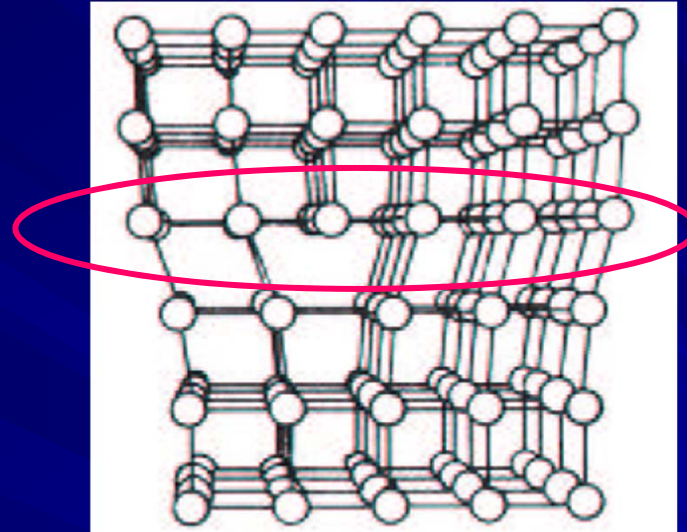
Frenkel-Kontorova model



Yakov Frenkel
(1894-1952)



Tatiana Kontorova
(1911-198X)



$$\frac{d^2 x_n}{dt^2} + \sin x_n - g(x_{n+1} + x_{n-1} - 2x_n) = 0.$$

Ya. Frenkel, T. Kontorova: Phys. Z. Sowietunion 13, 1 (1938)

Prandtl-Dehlinger model

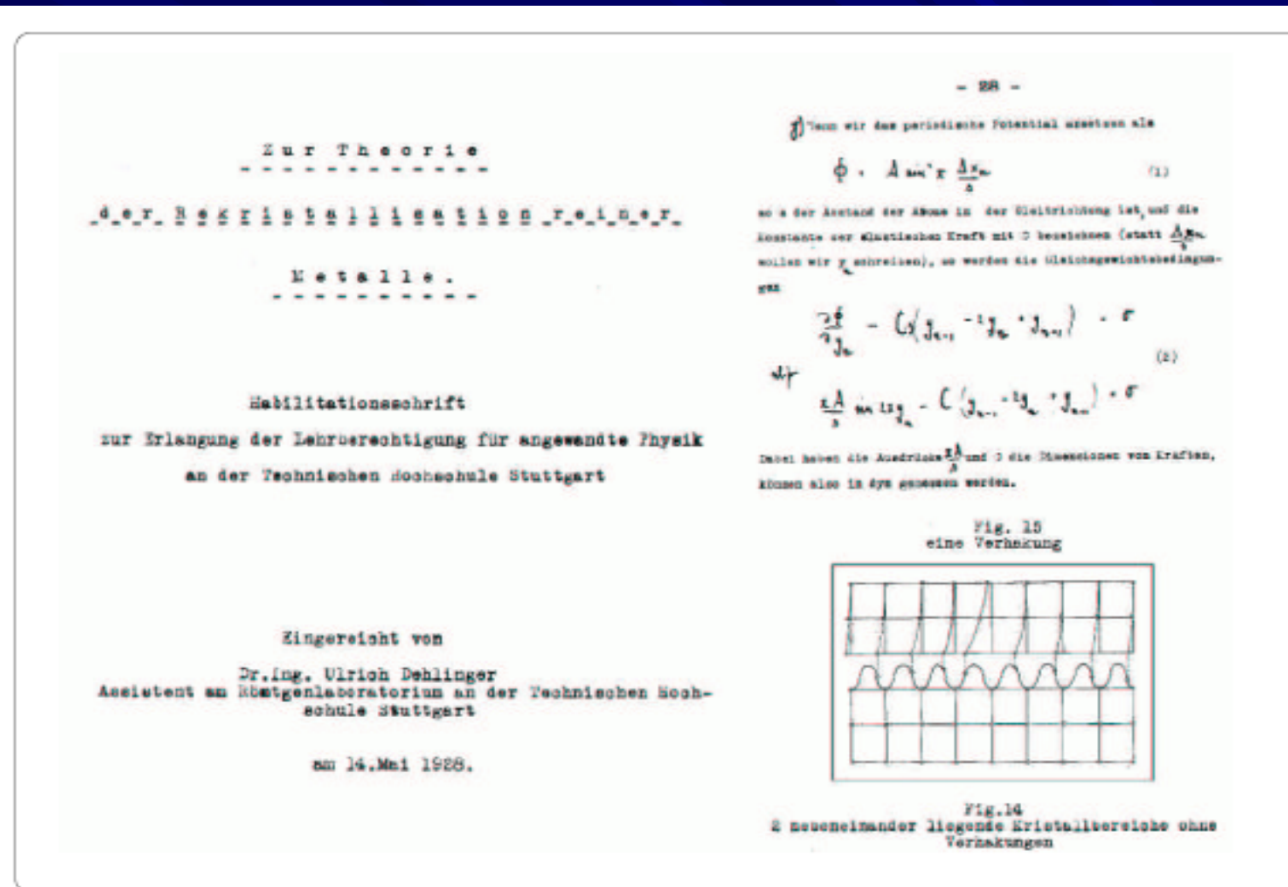
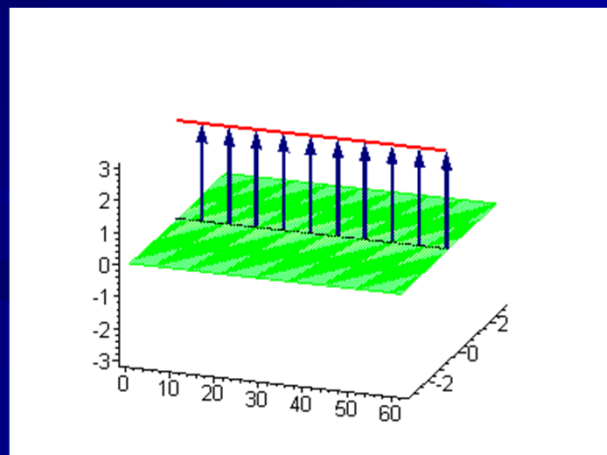
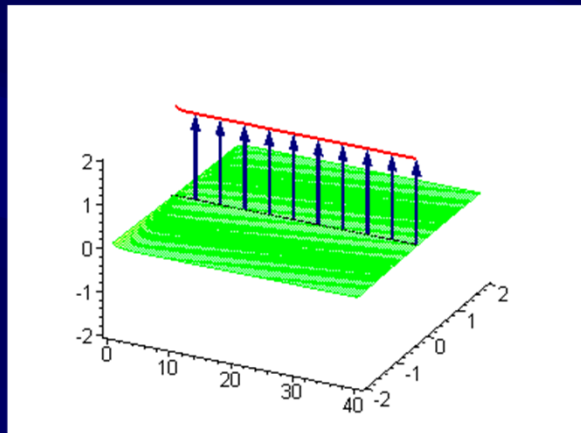


Fig. 13.1. Front page of the *Habilitationsschrift* of U. Dehlinger with excerpts. 'Verhakungen' are pairs of abrupt kinks of opposite sign or simply *kink pairs*.

L. Prandtl: Z. angew. Math. Mech. 8, 85 (1928)
U. Dehlinger: Ann. Phys. (Leipzig) 2, 749 (1929)

Sine-Gordon equation

$$\frac{\partial^2 u}{\partial t^2} - \frac{\partial^2 u}{\partial x^2} + \sin u = 0$$



O. M. Braun
Y. S. Kivshar

**The Frenkel-
Kontorova Model**
Concepts, Methods,
and Applications

 Springer

Russian Translation: 2008



Олег Браун –

доктор физико-математических наук,
ведущий научный сотрудник Института
физики Национальной академии наук
Украины

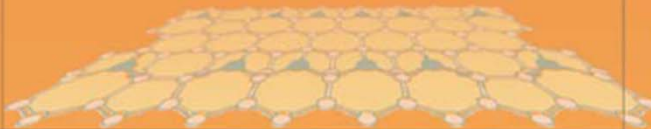


Юрий Кившарь –

профессор, директор Центра нелинейной
физики Австралийского национального
университета

Модель Френкеля – Конторовой. Концепции, методы, приложения

Первая книга, содержащая систематическое изложение концепций, методов и приложений нелинейной физики, основанных на модели Френкеля – Конторовой и ее приложениях. Рассмотрены нелинейная динамика дискретных систем, динамика солитонов и их взаимодействие, соизмеримые и несоизмеримые системы, статистическая механика нелинейных систем, расчеты и неравновесная динамика взаимодействующих многочастичных систем. Подробно обсуждаются основные нелинейные уравнения, свойства их локализованных решений и методы их анализа.



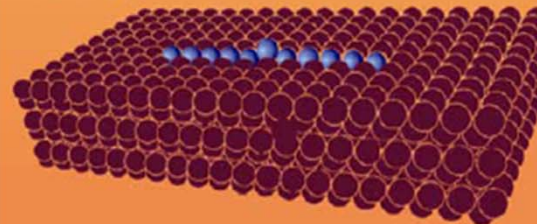
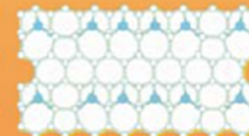
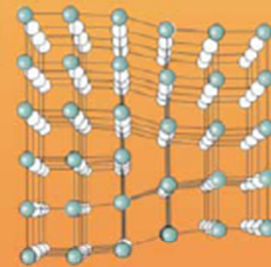
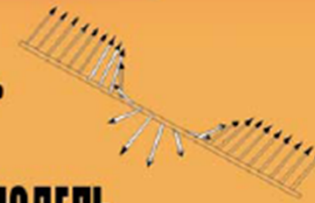
**О. М. Браун
Ю. С. Кившарь
МОДЕЛЬ ФРЕНКЕЛЯ – КОНТОРОВОЙ**



**О. М. Браун
Ю. С. Кившарь**

МОДЕЛЬ ФРЕНКЕЛЯ – КОНТОРОВОЙ

Концепции, методы, приложения



Recent advances

Importance of nonintergrable models

New types of localized modes: gap solitons, discrete breathers, compactons, self-trapped modes, azimuthons, etc

New media and materials:

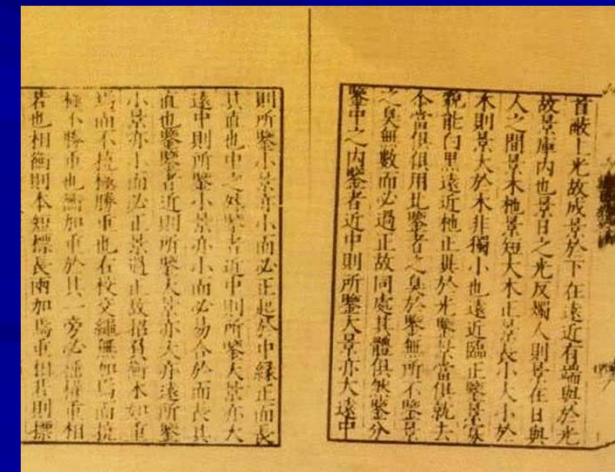
nonlinear optics: nonlocal media, discrete and subwavelength structures, plasmonics, slow light

Bose-Einstein condensates: nonlinearity management
nanostructures: graphene, carbon nanotubes

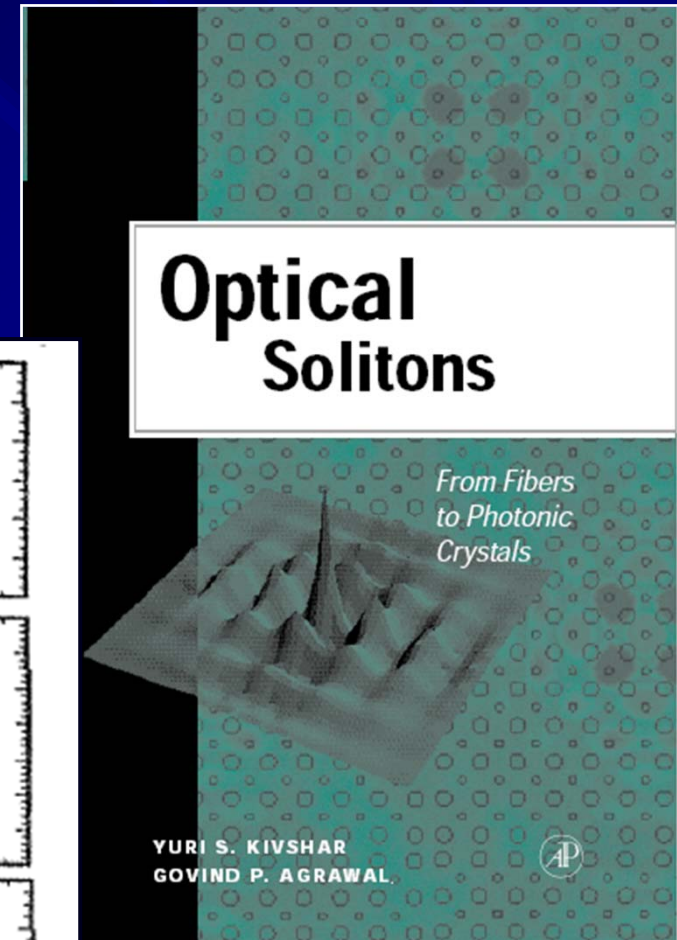
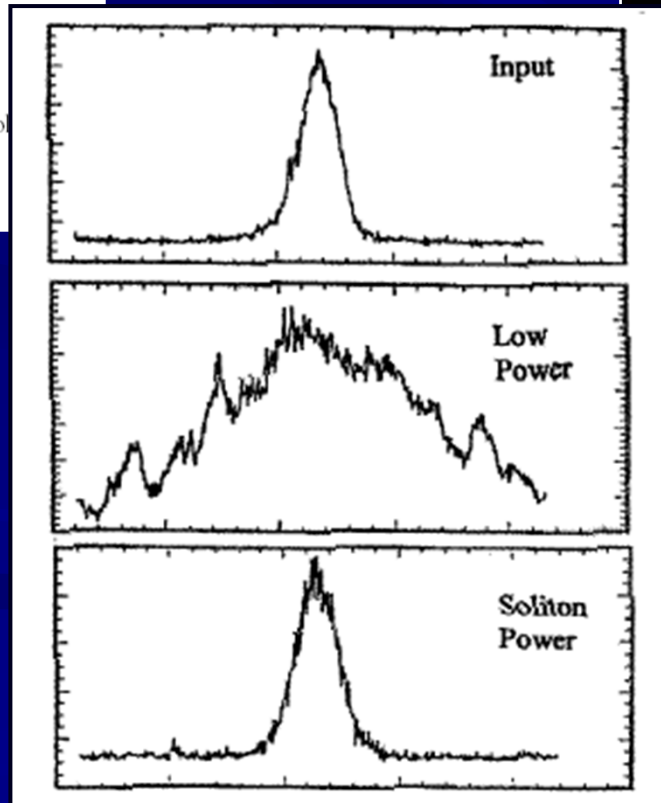
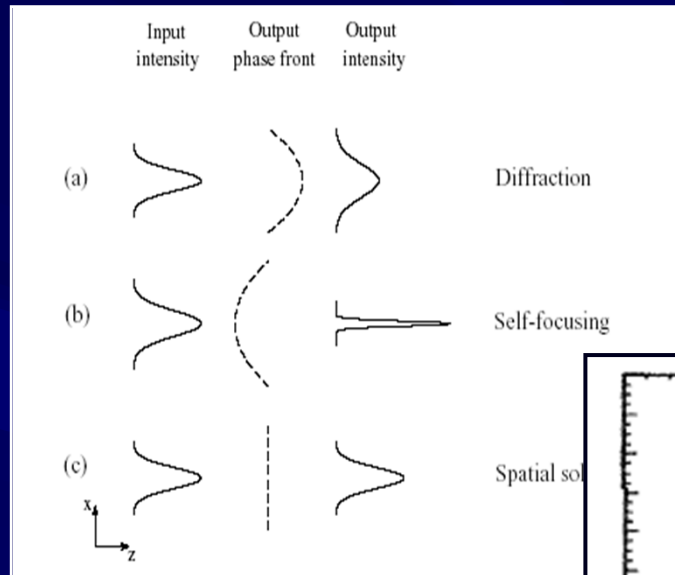
Why optics ?



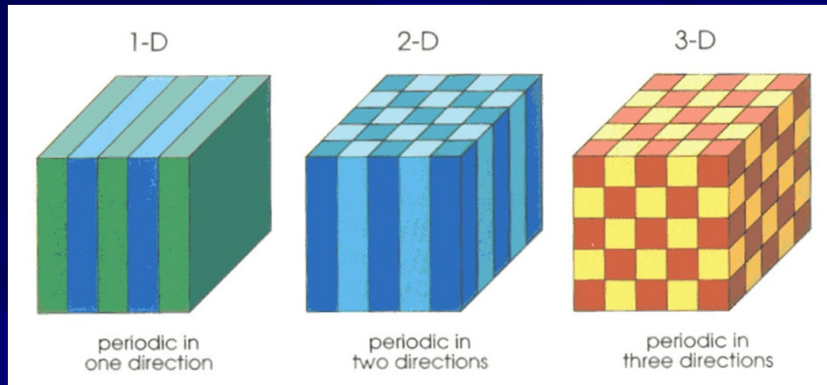
Mo Di (墨 翟)
468 BC~376 BC



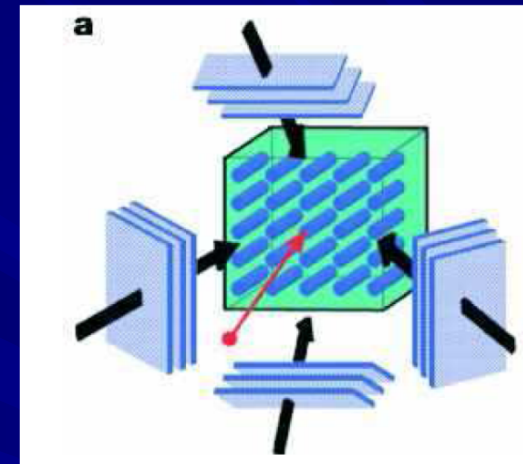
Self-focusing and spatial optical solitons



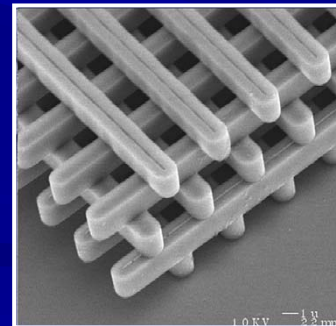
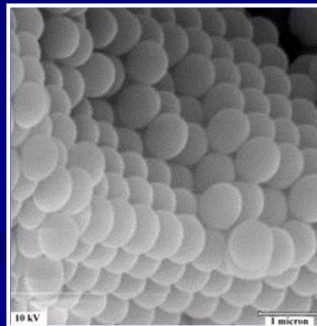
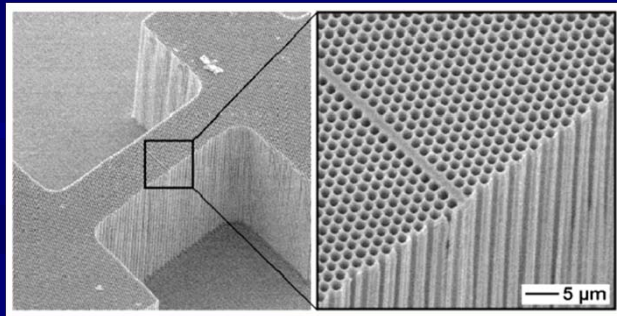
Photonic crystals and lattices



Optically induced



fabricated



How does periodicity affect solitons ?

