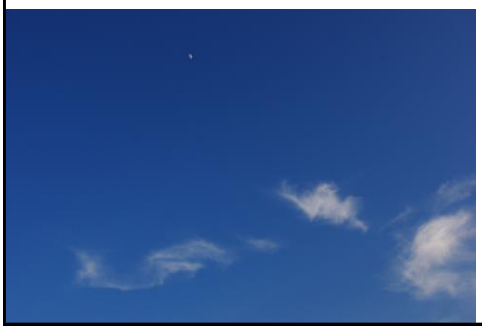
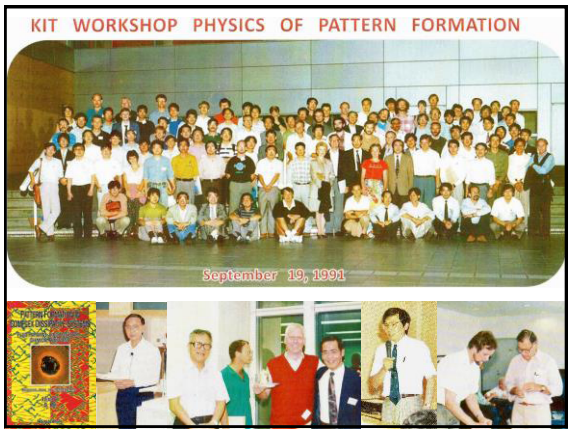
Hydro-chemical solitary wave inBZ-solution: the riddle of spe acceleration of the big wave

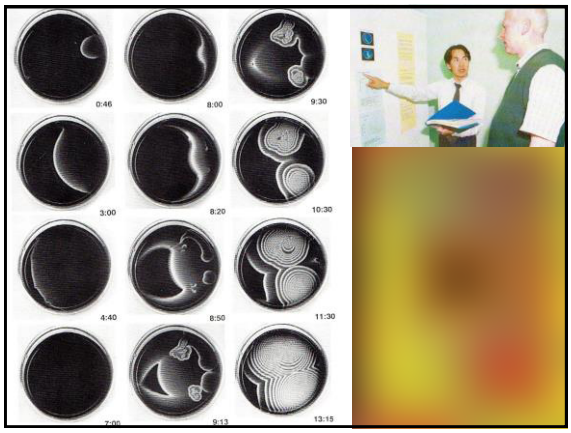
H. Miike (Yamaguchi University)

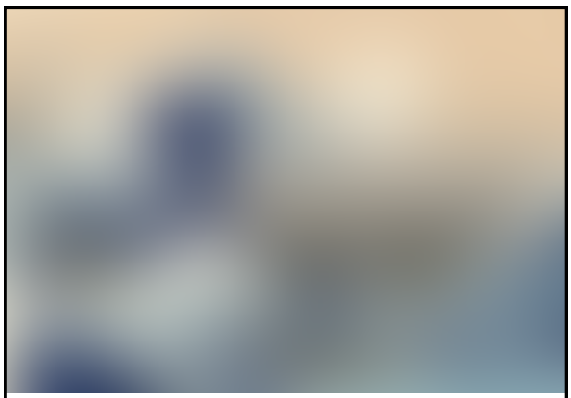
1 .The Big Wave appeared in KIT-workshop : 19th September, 1991 (Kokura, Japan)



山口大学

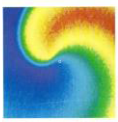






A Big Wave Kanagawa-Oki –Nami-Ura (K. Hokusai, 1836)

Spatio-Temporal Organization in Nonequilibrium Systems



Contributions to the Dortmunder Dynamische Woche June 1992

Edited by Stefan C. Müller and Theo Plesser

projekt verlag

A Big Chemical-Wave: Accelerating Propagation and Surface Deformation Induced by a Spontaneous Convection

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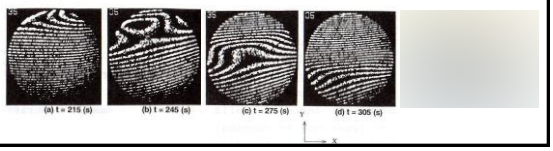
** *Faculty of Engineering, Kyushu Institute of Technology, Kitakyushu, 804 Japan*

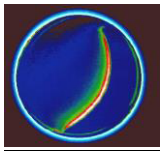
Abstract

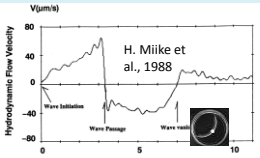
An acceleration of the propagation of a chemical wave accompanied with a remarkable hydrodynamic effects is observed in a thin solution layer of the Belousov-Zhabotinsky reaction. The quantitive measurements of surface deformation and induced convective flow are carried out by the Mach-Zehnder interferometer and by the sequencial image processing, respectively.

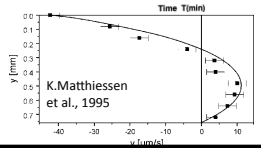


2. Convection induced by chemical wave propagation

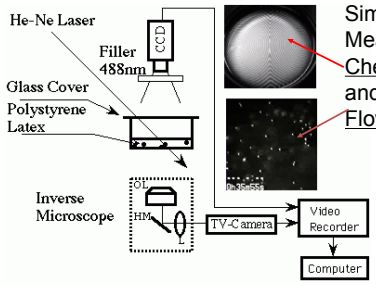
- A single chemical wave induces convective flow in a shallow layer of BZ-solution. The mechanism of the flow is regarded as a surface tension driven convection caused by concentration gradients of the reaction materials and catalysts.







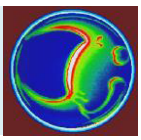
Determination of Flow Structure

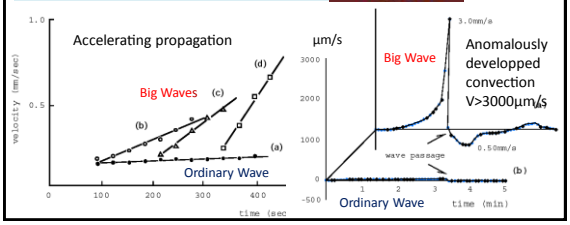


Simultaneous Measurement of Chemical Waves and Hydrodynamic Flow

2. Enhanced convection with accelerating chemical wave propagation

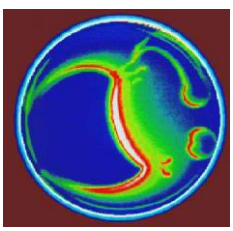
- A Big Wave having an accelerating propagation speed and enhanced convection was found in a shallow layer of BZ solution: H. Miike, H. Yamamoto, S. Kai, and S.C. Müller, Phys. Rev. E, 48(1993) R1627.





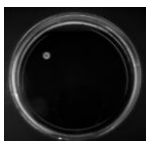
(2) Big Wave

- A curious chemical wave with acceleration of propagation velocity and enhanced convective flow:



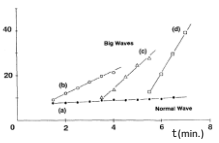
実験結果 (4)

・加速度的に伝搬する単一の化学反応波 Big Wave
- Miike et al. (1993) Phys. Rev. 48, p. R1627.

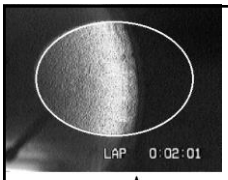


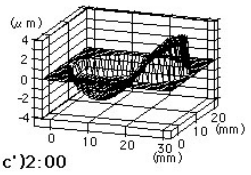
通常の伝搬波

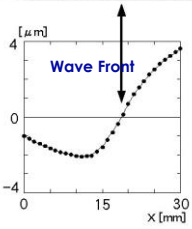
Big Wave



単一伝搬波の伝搬速度の時間変化
(a)通常の伝搬波, (b)～(d) Big Wave.





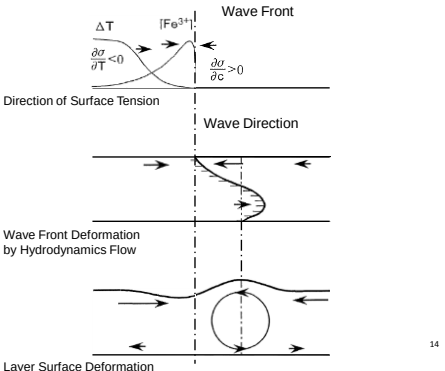


S.Kai et al., Physica D 84 (1995) 269

Big Waves

Having a global surface deformation measured by interferometer: about 6 μm
Hydro-chemical Soliton

ポイント：長波長の界面の変形を伴う



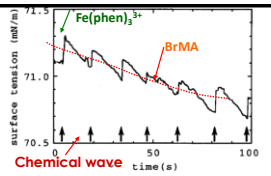


FIG. 1. Temporal variation of the surface tension caused by a chemical wave train. The arrow indicates the passage of a wave front at a measuring point.

O.Inomoto et. al., May, 2000 Phys. Rev. E, Vol.61, p.5326

Temporal trace of surface tension

1.Steep change synchronized with chemical waves:
$Fe(phen)_3^{3+}$: catalyst

2.Gradual decrease (trend): BrMA: reaction products

Surface tension of MA & BrMA

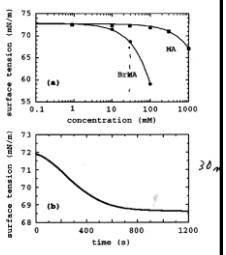
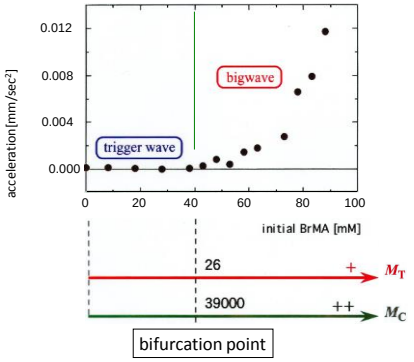


FIG. 3. (a) Surface activity of MA and BrMA. BrMA was prepared *in situ* in the BZR without ferroin. (b) Temporal change of the surface tension due to the adsorption process of BrMA.

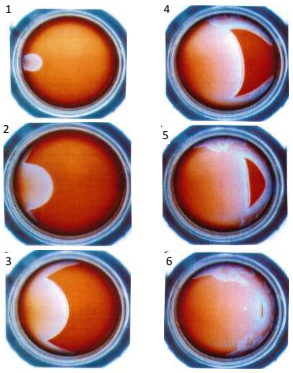
Big Waves

BrMA-Concentration Dependence of the Acceleration of Chemical Waves

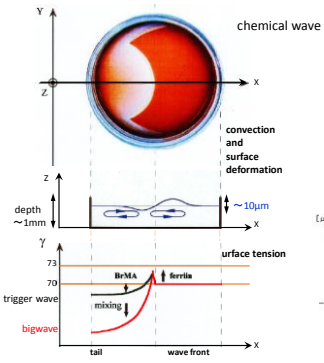


bifurcation point

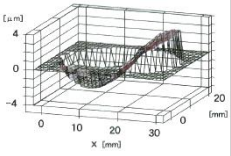
Bigwave Propagation in BZ-Reaction



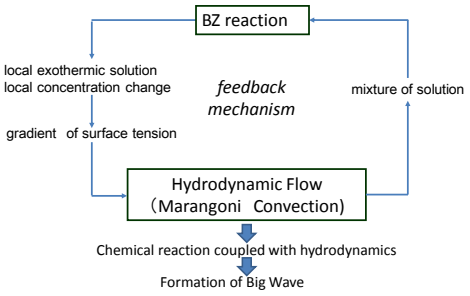
D. Kondepudi & I. Prigogine
Modern Thermodynamics
Bigwave Propagation in BZR
J. Wiley & Sons



対流によるミキシング
↓
BrMAの表面吸着を促進
↓
マランゴニ効果が顕在化



Coupling Scheme Between Reaction and Flow



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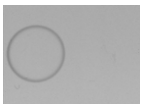
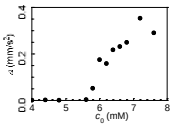
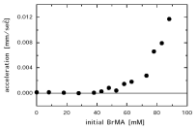
Frontal Acceleration in Excitable Media: O. Inomoto (2003)

- Iodate-arsenous acid reaction



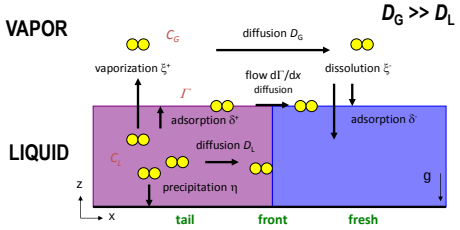


- BZ-reaction



- private communication

Overview of the system : O.Inomoto (2003)

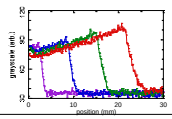
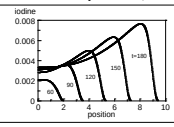
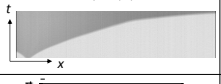
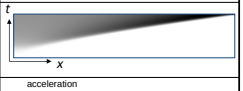
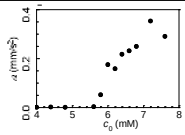
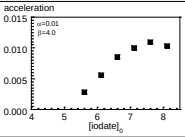


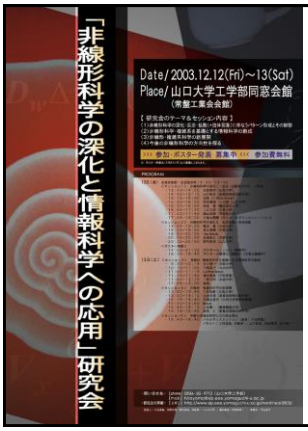
- private communication

Mathematical description (O. Inomoto, 2003)
in iodate-arsenous acid reaction

gas	$\frac{\partial c_G}{\partial t} = D_G \nabla^2 c_G + R_G$	iodine / gas phase $R_G = +\xi^+ c_L$ (vaporization)
interface	$\frac{\partial \Gamma}{\partial t} = D_S \nabla^2 \Gamma + \delta_L c_L + \delta_G c_G$	surface excess
	$\frac{\partial u_x}{\partial z} = \lambda \frac{\partial \Gamma}{\partial x}$	shear flow (b.c.)
liquid	$\frac{\partial c_L}{\partial t} + (u_i \cdot \nabla) c_L = D_L \nabla^2 c_L + R_L + F_i(c_i)$	iodine / liquid phase $R_L = +\xi^- c_G - \eta c_L$ (dissolution, precipitation)
	$\frac{\partial c_i}{\partial t} + (u_i \cdot \nabla) c_i = D_L \nabla^2 c_i + F_i(c_i)$	iodide, iodate, arsenous acid / liquid phase
	$\frac{\partial u_i}{\partial t} + (u_i \cdot \nabla) u_i = D_i \nabla^2 u_i - \frac{\partial p}{\partial x_i}$	convective flow
	$\sum_i \frac{\partial u_i}{\partial x_i} = 0$	continuity

Comparison of results: O.Inomoto, 2003

	experiment	calculation (a=0.001, b=5.0)
profile (I_2 distribution)		
space-time plot		
instability		

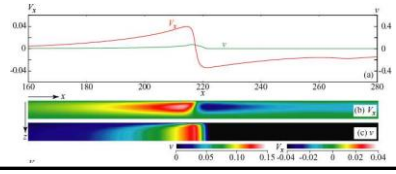


非線形科学の深化/研究会
2003.12.12-13: 山口大学工学部

- 反応拡散＋流体現象に 関する4つの講演(モデル)
- 猪本修:九州大学
- 長山雅晴:京都大学
- 北畑裕之:京都大学
- 野村厚志:山口大学

Reaction-Diffusion-Convection models trying to explain convection associated with chemical waves

- 1995: H. Wilke, Physica D 86
- 1996: K. Matthiessen et al., Phys. Rev. E 53
- 1996: M. Diewald et al., Phys. Rev. Lett. 77
- 2003: H. Kitahata et al., J. Chem. Phys. 116
- 2003: O. Inomoto et al., non-published
- 2005: A. Nomura et al., non-published
- 2013: ??



A. Nomura, 2005
Viscous-Elastic
Surface Model

August, 1974
Mt. Kuju, Oita

Thank you for your kind attention.

Spatio-temporal Organization
in Non-equilibrium Systems,
23rd February, 2013

5th January, 1977

Prof. Hirakawa
and his Family