4.
DC Gas-Discharge Systems: Experiment

(references refer to the list of publications given in chapter 12)

A. Quasi 1-dimensional dc systems

A. 4.1 General remarks

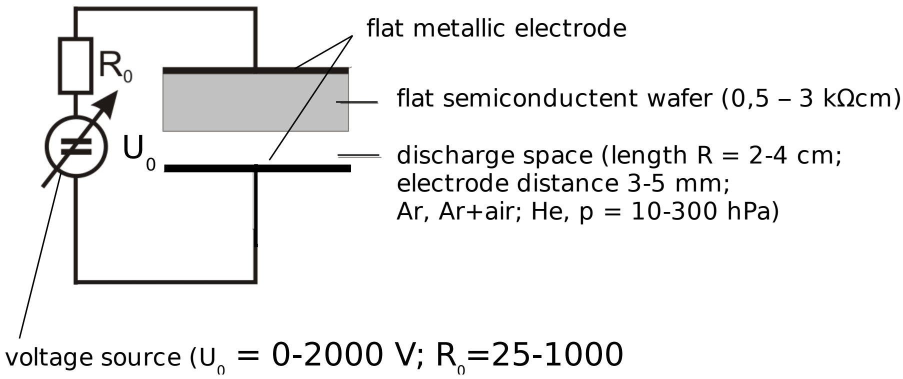

Fig. 4.1

Patterns in quasi 1-dimensional gas-discharge systems are recorded in the gas space of the device fig. 4.1 most easily via the luminescence radiation density being emitted vertically to the planes defined by the electrodes. In most cases the radiation density is proportional to the current density. Of particular interest are solitary current filaments that show up in the radiation distribution as bright (dark) objects on a stationary homogeneous low (high) current background. Such filaments generate solitary spots or localized structures (LSs) in 1-dimensional space arising from the intersection of the filaments with a line in the gas space parallel to the edges of the electrodes.

Schematically the device can be considered as consisting of a high ohmic layer L (the semiconductor) and a highly nonlinear layer NL (the gas) with S shaped local (current density)-(voltage) characteristic as depicted in the figs. 2.1, 2.2 of the chapter A Model for Pattern Formation. This model delivers a qualitative description of the observed patterns. A quantitative gas-discharge specific modelling is based on a set of drift diffusion equations supplemented by the Poisson equation. This is discussed in more detail in Gas-Discharge: Theory.

As discussed in the Introduction and in the chapter A Model for Pattern Formation usually the experiments are performed with $R_0 \neq 0$ or a real voltage source. In these cases, solitary LSs generated by filaments cannot be considered as dissipative solitons (DSs) per se. However, in many circumstances the qualitative shape of the local (current density)-(voltage) characteristic is similar to the "realistic" curve in fig. 2.2 of the chapter A Model for Pattern Formation. In these circumstances also for $R_0 \neq 0$ (or a real voltage source) filaments in gas-discharge systems generate DSs to good approximation, at least when dealing with bright objects. In addition in most cases in which LS are observed under the described conditions, DSs will exist in the absence of a finite series resister or a real voltage source. In the following, when reporting on experimental results without exception the term filament is used. In contrast, when reporting theoretical results obtained from the generalized FitzHug-Nagumo (FHN) equations (1-3) of chapters A Model for Pattern Formation and Reaction-Diffusion Equations we use the terms LS or DS.

A. 4.2 Graphical representation of selected results

The following is a series of figures reflecting main results that have been obtained experimentally in relation to the investigation of quasi 1-dimensional dc gas-discharge systems fig. 4.1.

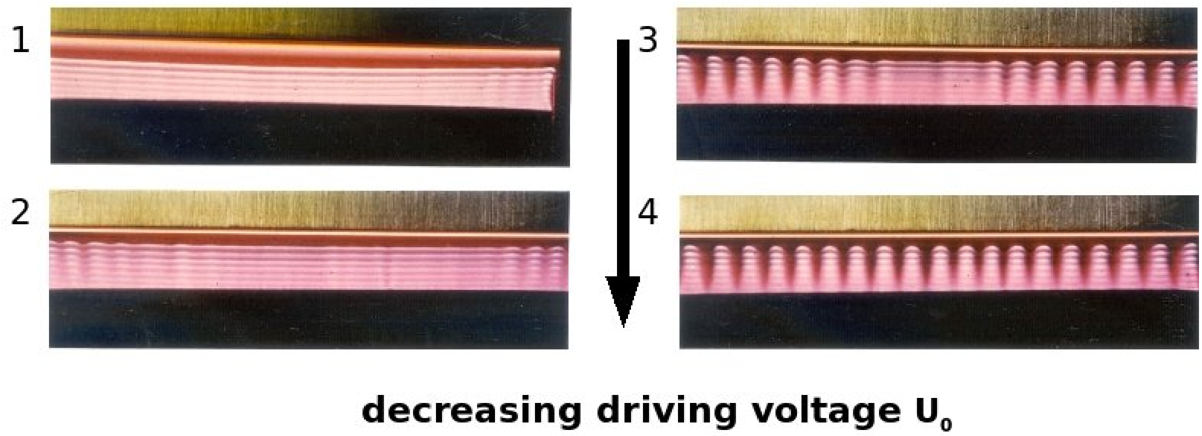

Fig. 4.2

Experimentally observed self-organized periodic patterns on the quasi 1-dimensional dc gas-discharge system fig. 4.1 exhibiting a supercritical (Turing) bifurcation from the stationary homogeneous state to stationary periodic pattern. Bright areas denote high luminescence radiation density in the discharge space (gas) of fig. 4.1. The driving voltage U_0 is decreased from (1) to (4). [Pu012; Pu016; Pu017; Pu018; Pu023] - compare to: experiment figs. 3.10, 4.3, 4.11, 4.13, 5.4

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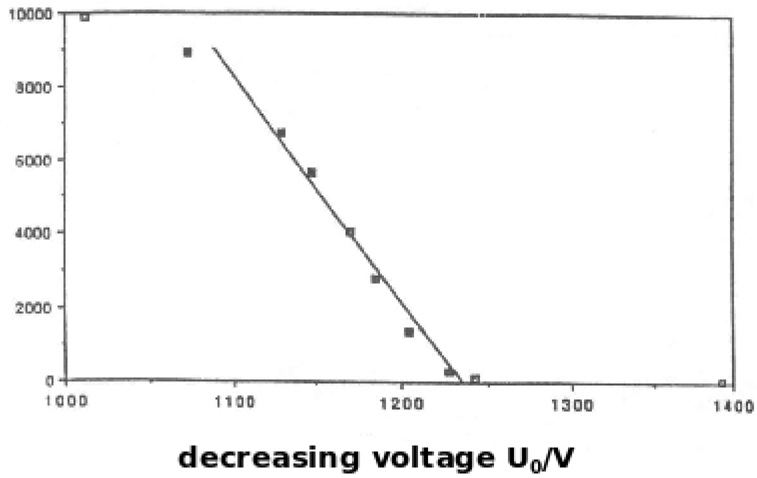

Fig. 4.3

Evaluation of the bifurcation scenario of fig. 4.2: square of the fundamental Fourier mode of the periodic patterns as a function of the bifurcation parameter *U_0*. To good approximation a square law is obtained, as expected from theory for a supercrititcal Turing bifurcation. [Pu016, Pu018] - compare to: experiment figs. 3.10, 4.2, 4.11, 4.13, 5.4

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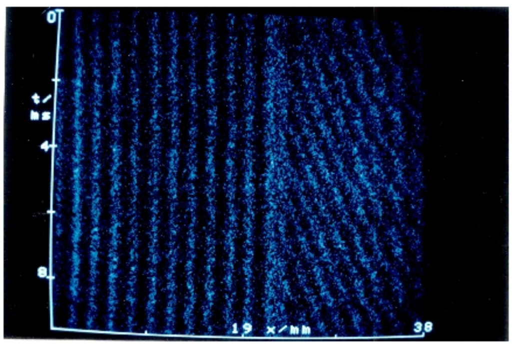
a)



b)

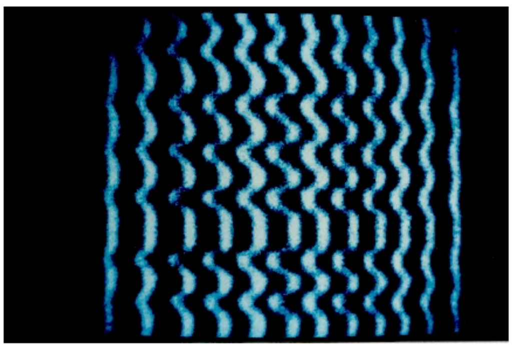


Fig. 4.4a,b

In addition to stationary periodic patterns like those of fig. 4.2 various kinds of non-stationary periodic patterns have been observed when varying the parameters of the system fig. 4.1. Corresponding records made with a streak camera are represented in a space (abscissa) time (ordinate) plot. One observes e.g. the simultaneous existence of a stationary and a travelling periodic pattern (a) and a periodically oscillating pattern (b). [Pu016]

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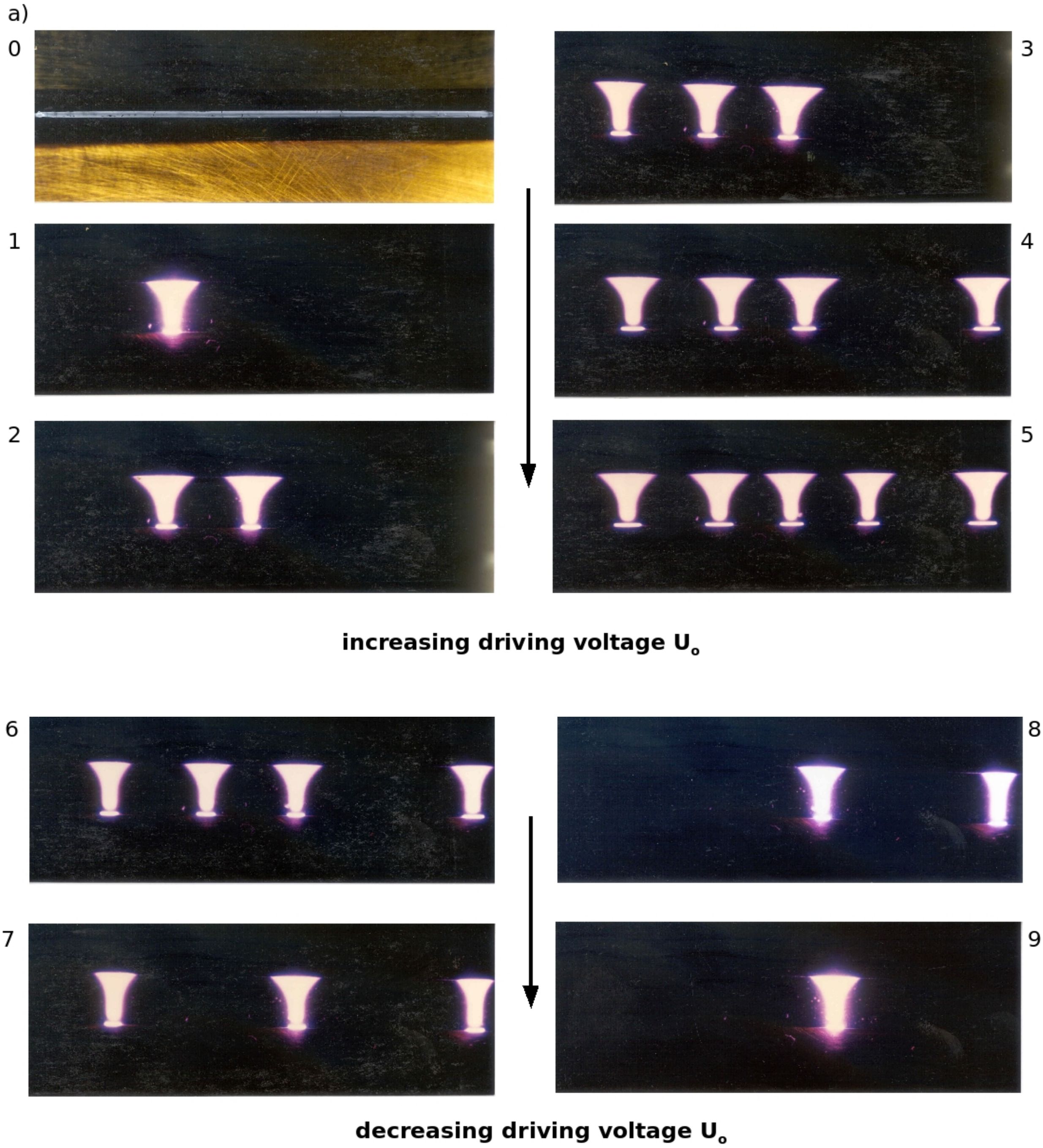

Fig. 4.5a,b

Stationary solitary current filaments in the quasi 1-dimensional gas-discharge system fig. 4.1 in the presence of a global coupling. When increasing (0 to 5) and decreasing (6 to 9) the driving voltage U_0, a cascades of stationary filaments with increasing and decreasing number is obtained. In general filaments are generated by splitting with subsequent repulsion. [e.g. Pu005; Pu012; Pu015; Pu043] - compare to: experiment figs. 3.12, 4.6, 4.16, 5.7, 5.18, 7.3, 7.10; theory figs. 3.12, 9.6, 9.10

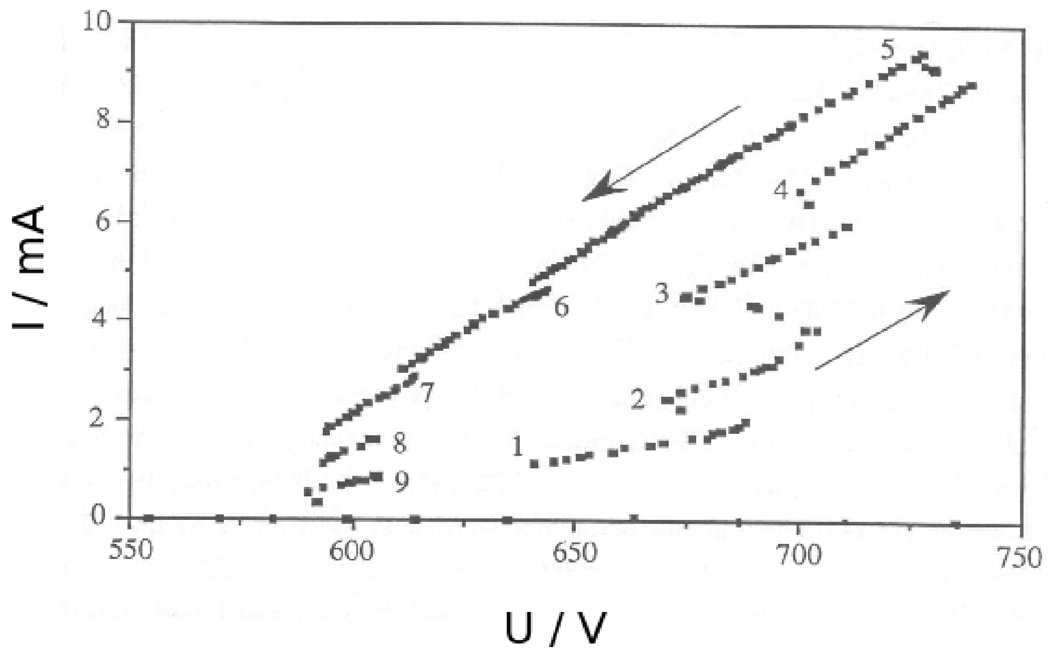

Fig. 4.6

Global current *I* (total current through the device) versus voltage drop at the device *(U_0 – IR_o)* for the measurements of fig. 4.5. The numbers correspond to those of the fig. 4.5 [[e.g. Pu012; Pu015] - compare to: experiment figs. 3.12, 4.5, 4.16, 5.7, 5.18, 7.3, 7.10; theory figs. 3.12, 9.6, 9.10

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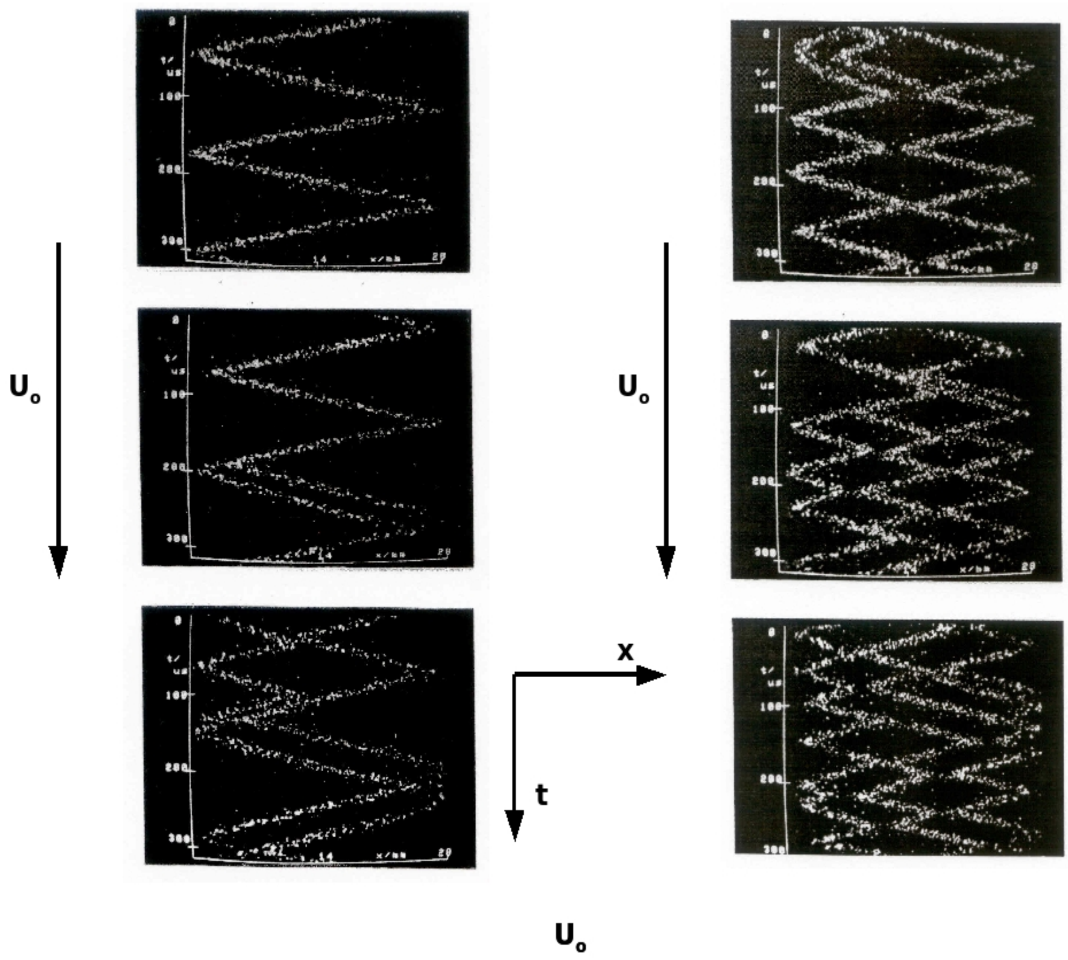

Fig. 4.7

Travelling solitary filaments in the quasi 1-dimensional gas-discharge system fig. 4.1. recorded by a streak camera and represented in a space-time plot. When increasing the driving voltage *U_0* (from top to bottom and from left to right) a cascades of travelling and interacting filaments with increasing number is obtained. Bright areas denote high luminescence radiation density in the discharge space (gas) of fig. 4.1. Reflection at the boundary and at each other, formation of bound states, generation as well as annihilation are frequently observed phenomena. [Pu021; Pu026: Pu043] - compare to: experiment figs. 3.13, 3.14, 4.18, 4.19, 5.9, 7.2; theory figs. 8.1, 9.8, 9.13, 9.14, 9.15

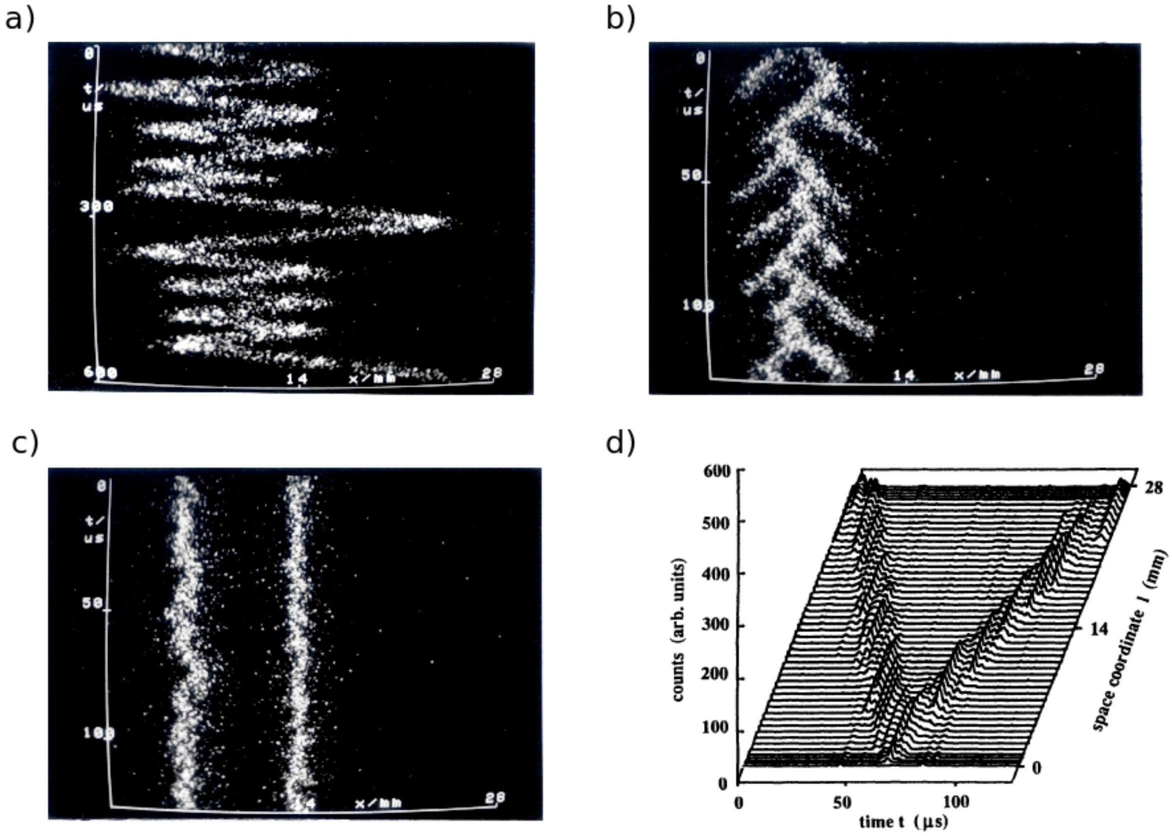

Fig. 4.8a-d

In addition to fig. 4.7 various other kinds of temporal behaviour of solitary current filaments are observed in the space-time plot when varying parameters in the dc system fig. 4.1: irregular reversion of direction of propagation of a single filament (a), fishbone pattern with periodic splitting and subsequent annihilation (b), coexistence of a pendulating and a stationary filament (c) [Pu015, Pu018, Pu021, Pu023] and periodic generation of two filaments in the centre by splitting and propagation to the boundary with subsequent annihilation. The latter dynamics of individual filaments may be superimposed by oscillations (d) [Pu021] - compare to: theory fig. 9.7

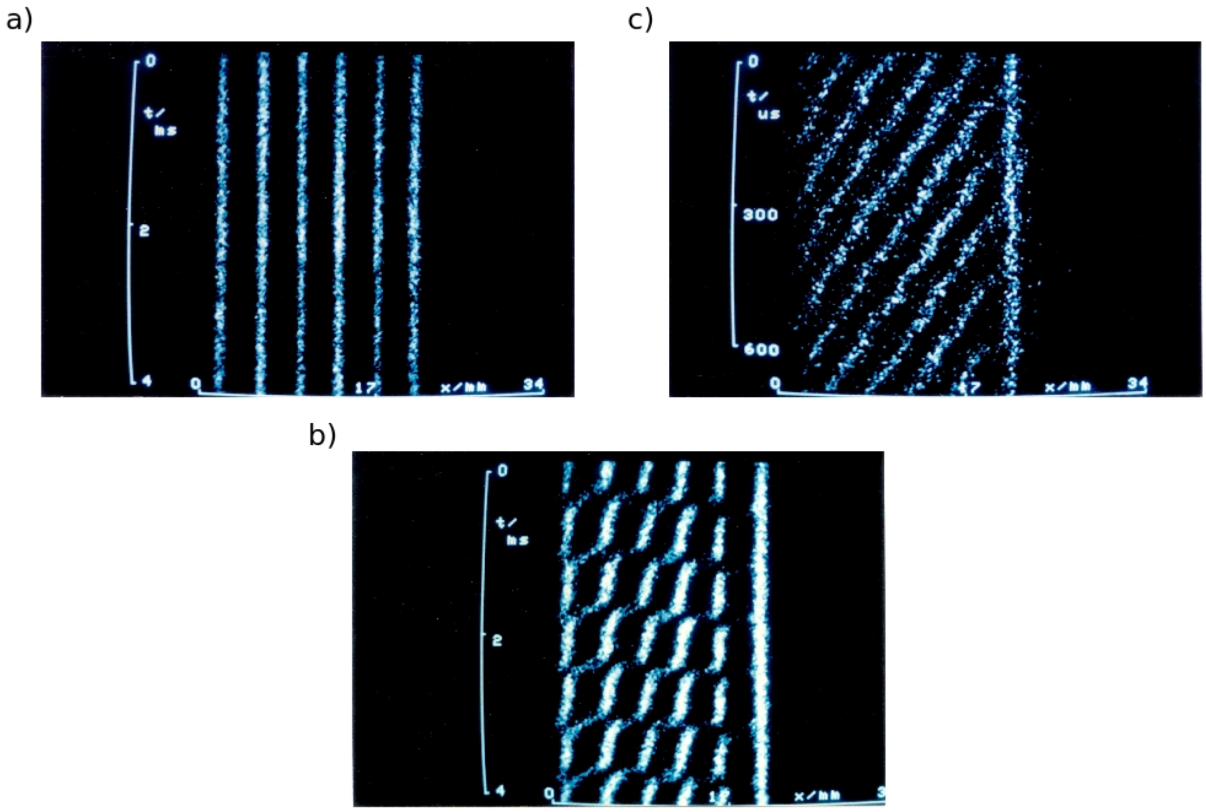

Fig. 4.9a-c

Typical influence of a magnetic field being oriented vertical to the plane defined by the electrodes of the quasi 1-dimensional dc gas-discharge fig. 4.1 in the case of a stationary periodic arrangement of filaments. The results are obtained by means of a streak camera and are represented with the abscissa as the space coordinate and the ordinate as the time. The magnetic fields are as follows: 0 mT (a), 17 mT (b) and 28 mT (c) [H. Willebrand, “Strukturbildung in lateral ausgedehnten Gasentladungssystemem”, Thesis, University of Münster (1992)] .

A. 4.3 Listing of main results

With respect to the abbreviations used in the following listing of observed phenomena we refer to the Introduction.

Pu005: Radehaus, Dirksmeyer, Willebrand, Purwins (1987)

isolated stat fs

exp: 1d-dc-GDS, $R_0 \neq 0$ - stat fs

theo: 2-k + gc, R^1 - num: stat DSs (mentioned)

bifurcation: snaking

exp: 1d-GDS – snaking

theo: 2-k + gc, R^1 - num: snaking (mentioned)

first experimental detection of solitary filaments in gas-discharge systems with high ohmic barrier - first claim, that these planar dc gas-discharge devices can be considered as r-d systems with respect to lateral patter formation - experimental detection of snaking - detection of splitting of DSs in the course of parameter change - see also: Reaction-Diffusion Equations

Pu007: Purwins, Klempt, Berkemeier (1987)

isolated stationary fs

exp : 1d-dc-GDS, $R_0 \neq 0$ - stat fs

theo: 2-k + gc, R^1 stat DSs

splitting of fs

exp: 1d-dc-GDS, $R_0 \neq 0$ – increase of number of fs by splitting while increasing the driving voltage

bifurcation: snaking

exp: 1d-dc-GDS, $R_0 \neq 0$ - snaking

theo: 2-k + gc, $R^{1,2}$ – snaking

interpretation of the quasi 1-dimensional dc gas-discharge device as a 2-layer system consisting of a high ohmic and a strongly nonlinear layer with monotonous and S-shaped local current-voltage characteristic respectively being described by a 2-component reaction-diffusion equation - presentation of a basic model for the universal behaviour of a relatively large class of pattern forming systems including biological, chemical and physical systems - detection of snaking - detection of solitary filaments and related DS splitting - see also: Electrical Networks: Experiment and Theory, Semiconductors: Theory, Reaction-Diffusion Equations

Pu008: **Purwins, Radehaus C. Radehaus, and J. Berkemeier (1987)**

isolated stationary fs

exp: 1d-dc-GDS, $R_0 \neq 0$ - stat fs

theo: 2-k + gc, $R^{1,2}$ - stat DSs

splitting of fs

exp: 1d-dc-GDS, $R_0 \neq 0$ – increase of number of fs by splitting while increasing the driving voltage

bifurcation: snaking

exp: 1d-dc-GDS, $R_0 \neq 0$ - snaking

theo: 2-k + gc, $R^{1,2}$ – snaking

see [Pu007] - see also: Electrical Networks: Experiment and Theory, Reaction-Diffusion Equations

Pu011: **Purwins, Radehaus, Dirksmeyer, Dohmen, Schmeling, Willebrand (1989)**

isolated stationary fs

exp : 1d-dc-GDS - stat fs

theo: 2-k, $\mu \neq 0$ + gc , R^1 - num: stat DSs

splitting of fs

exp : 1d-dc-GDS - increase of number of fs by splitting while increasing the driving voltage

theo: 2-k, $\mu \neq 0$ + gc, R^1 – num: increase of number of DSs by splitting while increasing the driving voltage

bifurcation: snaking

exp : 1d-dc-GDS - snaking

theo: 2-k, $\mu \neq 0$ + gc, R^1 – num: snaking

focus on the importance of the activator-inhibitor principle for the investigated reaction-diffusion equation and the formation of localized structures in physical systems - splitting of solitary filaments and relate DSs due to parameter change - **see also: Electrical Networks: Experiment and Theory, Reaction-Diffusion Equations**

Pu012: **Willebrand, Radehaus, Niedernostheide, Dohmen, Purwins (1990)**

isolated stationary fs

exp: 1d-dc-GDS, $R_0 \approx 0$, $R_0 \neq 0$ - stat fs

theo: 2-k, $\mu \neq 0$ + gc, R^1 – num: stat DSs (mentioned)

splitting of fs

exp: 1d-dc-GDS, $R_0 \approx 0$, $R_0 \neq 0$ - stat f splitting due to parameter change

periodic pattern in R^1

exp: 1d-dc-GDS, $R_0 \approx 0$, $R_0 \neq 0$ - stat periodic

theo: 2-k + gc, R^1 – anal: stat periodic (mentioned)

bifurcation: snaking, Turing

exp: 1d-dc-GDS, $R_0 \approx 0$, $R_0 \neq 0$ - snaking

theo: 2-k + gc, R^1 – num: snaking (mentioned)

exp: 1d-dc-GDS, $R_0 \approx 0$, $R_0 \neq 0$ - (stat hom) ↔ (stat periodic), supercritical Turing bif

theo: 2-k + gc, R^1 – anal: (stat hom) ↔ (stat periodic), supercritical Turing bif (mentioned)

experimental detection of a supercritical Turing bifurcation in the 1-dimensional dc gas-discharge system - very clear experimental evidence

for snaking in 1-dimensional dc gas-discharge system - mention that the Turing bifurcation, isolated DSs and snaking are solutions of the 2-component reaction-diffusion equation - the experimental work is described also in [H. Willebrand, Diplom-Arbeit, University of Münster (1988) and H. Willebrand, Thesis, University of Münster (1992)]

Pu015: Willebrand, Niedernostheide, Ammelt, Dohmen Purwins (1991)

isolated stationary fs

exp: 1d-dc-GDS, $R_0 \neq 0$ - stat fs

splitting of fs

exp: 1d-dc-GDS, $R_0 \neq 0$ - in the course of time: periodically repeated splitting of a single fs and subsequent disappearance of the additional fs; in the course of time: repeated splitting of one f in an ensemble of almost equidistant fs and subsequent merging of neighbouring one; irregular appearance and disappearance of fs in the latter

generation, annihilation of fs

exp: 1d-dc-GDS, $R_0 \neq 0$ - various gen and anni processes occurring spontaneously or in the course of interaction

many f systems

exp: 1d-dc-GDS, $R_0 \neq 0$ - many non-stationary fs exhibiting various generation and annihilation processes occurring spontaneously or in the course of interaction

bifurcation: snaking

exp: 1d-dc-GDS, $R_0 \neq 0$ - snaking

experimental detection of complex dynamics of solitary filaments and related DSs: generation by splitting, spontaneous individual annihilation and merging in a parameter range near to formation of new filaments in the snaking scenario - see also: [Pu018; H. Willebrand, Thesis, University of Münster (1992)]

Pu16: Willebrand, Matthiessen, Niedernostheide, Dohmen, Purwins (1991)

periodic pattern in R^1

exp: 1d-dc-GDS, $R_0 \neq 0$ - stat; trav; oscillating; coexistence of stat period with trav period pattern on the same domain - generation of a new stripe in the space time plot and corresponding shift of the rest of the pattern to stick to the original wave number; stat hom ↔ stat periodic, supercritical Turing bif with correct scaling law; subcritical bif of the latter type; bif diagram with pressure and electrode distance as parameters: spatially inhom, spatially inhom, soat

bifurcation: Turing

exp: 1d-dc-GDS, $R_0 \neq 0$ - (stat hom) ↔ (stat periodic), supercritical Turing bif with correct scaling law

experimental detection of a supercritical Turing bifurcation in the quasi 1-dimensional gas-discharge system with correct scaling law - various dynamical phenomena of periodic patterns - the corresponding experimental work is described also in [H. Willebrand, Diplom-Arbeit, University of Münster (1988)] - see also [H. Willebrand, Thesis, University of Münster (1992)]

Pu017: Radehaus, Willebrand, Dohmen, Niedernostheide, Bengel, Purwins (1992)

periodic pattern in R^1

theo: modified 2-k + gc , R^1- anal: period

bifurcation: Turing

exp: 1d-dc-GDS, $R_0 \neq 0$ - (stat hom) ↔ (stat periodic), supercritical and subcritical Turing bif, the former with correct scaling law

theo: modified 2-k + gc , R^1 - anal: (stat hom) ↔ (stat periodic), supercritical and subcritical Turing bif

treatment of the experimentally observed supercritical and subcritical Turing bifurcation in terms of a modified 2-component reaction diffusion equation using centre manifold theory - see also: Reaction-Diffusion Equations

Pu018: Niedernostheide, Dohmen, Willebrand, Schulze, Purwins (1992)

isolated stationary fs

exp : 1d-dc-GDS , $R_0 \neq 0$ - stat fs

theo: 2-k + gc, R^1 - num: stat DSs

splitting of fs

exp: 1d-dc-GDS , $R_0 \neq 0$ - splitting of fs while increasing the external driver - in the course of time repeated splitting of fs and subsequent disappearance of the additional one

theo: 2-k, $\mu \neq 0$ + gc, R^1 - num: splitting of DSs while increasing the external driver

periodic pattern in R^1

exp: 1d-dc-GDS , $R_0 \neq 0$ - stat pattern

theo: modified 2-k + gc , R^1- anal: period

bifurcation: snaking, Turing

exp: 1d-dc-GDS , $R_0 \neq 0$ - snaking

theo: 2-k + gc, R^1 - num: snaking

exp: 1d-dc-GDS, $R_0 \neq 0$ - (stat hom) ↔ (stat periodic), supercritical bif with correct scaling law

theo: modified 2-k + gc , R^1 - anal: (stat hom) ↔ (stat periodic), supercritical Turing bif

most of the material is contained in previous work - see also: Reaction-Diffusion Equations

Pu021: Willebrand, Hünteler, Niedernostheide, Dohmen Purwins (1992)

isolated stationary and travelling fs

exp: 1-dc-GDS, $R_0 \neq 0$ - stat, trav fs; periodic gen at one boundary 1, trav to the second boundary, annni at the latter and related simultaneous gen at the first one

isolated pendulating fs

exp: 1-dc-GDS, $R_0 \neq 0$ - pend fs

splitting of fs

exp: 1-dc-GDS, $R_0 \neq 0$ - splitting in the course of propagation with fishbone like structure in the space-time plot

interaction of fs: reflection

exp: 1-dc-GDS, $R_0 \neq 0$ - refl at boundary and at each other

interaction of fs: formation of molecules

exp: 1-dc-GDS, $R_0 \neq 0$ - collision of counter propagating fs with consecutive propagation in the same direction (possibly molecule formation)

generation, annihilation of fs

exp: 1-dc-GDS, $R_0 \neq 0$ - gen and anni of 1- and 2- fs

many f systems

exp: 1-dc-GDS, $R_0 \neq 0$ - larger number of moving and interacting fs

bifurcation of DSs: "dynamical snaking"

exp: 1-dc-GDS, $R_0 \neq 0$ - bif cascade to increasing number of trav (and interacting) fs

experimental detection of travelling solitary filaments and related DSs in quasi 1-dimensional dc gas-discharge systems including various kinds of interaction, generation and annihilation - discovery of many body systems with well defined intrinsically travelling filaments and related DSs as elementary building blocks – "dynamical snaking": bifurcation cascade to increasing number of trav (and interacting) DSs

Pu023: Willebrand, Niedernostheide,Dohmen, Purwins (1993)

summary - material also contained in [Pu015, Pu16, Pu17, Pu18] - see also: Reaction-Diffusion Equations

Pu026: Willebrand, Or-Guil, Schilke, Purwins, Astrov (1993)

experimental material also contained in [Pu021] - solutions of the 2-component reaction-diffusion equations in 1-dimensional space reproduce experimentally observed reflection of travelling solitary filaments and related DSs at the boundaries and periodic reflection of two filsmrents at each other - see also: Reaction-Diffusion Equations

Pu043: Bode, Purwins (1995)

isolated stationary and traveling fs

exp: 1d-dc-GDS, $R_0 \neq 0$ - stat, trav fs

interaction of fs: formation of molecules

exp: 1d-dc-GDS, $R_0 \neq 0$ - trav 2- fs

interaction of fs: reflection

exp: 1d-dc-GDS, $R_0 \neq 0$ - ref at each other and at boundary; single fs; collision of counter propagating fs with consecutive propagation in the same direction

exp: 1d-dc-GDS, $R_0 \neq 0$ - refl at boundary and at each other

generation, annihilation of fs due to interaction

exp: 1-dc-GDS, $R_0 \neq 0$ - gen, anni by collision

many f systems

exp: 1-dc-GDS, $R_0 \neq 0$ - larger number of moving and interacting fs

bifurcation: snaking

exp: 1d-dc-GDS, $R_0 \neq 0$ - snaking; "dynamical snaking"

summary of parts of the works of e.g. [Pu21, Pu023] - see also: Electrical Networks: Experiment and Theory, Reaction-Diffusion Equations

Pu051: **Ammelt, Astrov, Purwins (1996)**
summary - parts of the works e.g. [Pu012, Pu015, Pu021]

Pu078: **Purwins, Astrov, Brauer (2001)**
summary - experimental observation of filamentary and other patterns in planar gas-discharge systems observed in previous work

Pu083: **Purwins, Astrov, Brauer, Bode (2001)**
summary - experimental observation of filamentary patterns and related DSs based on static and dynamic patterns in planar gas-discharge systems observed in previous work - comparison of the experimental results with solutions of the 2- and 3-component reaction-diffusion model

Pu127: **Purwins, Amiranashvili (2007)**
summary - simple patterns: e.g. isolated solitary filaments and related DSs, stripes, hexagons and rotating spirals - patterns of higher complexity with solitary filaments and related DSs as elementary building blocks: "molecules", "many body systems" in the form of crystal-, liquid- and gas-like arrangements, chains, nets - universal behaviour for a certain class of systems including: planar ac and dc gas-discharge systems, electrical networks, semiconductor layer systems, chemical solutions and biological systems - theoretical definition of the corresponding universality class: writing down a 3-component reaction-diffusion system serving as a kind of normal form for the qualitative description of the experimentally observed self-organized patterns - illustration of the formation of DSs in planar electrical transport systems on the basis of the 2-component reaction diffusion equation - see also: Electrical Networks: Experiment and Theory, AC Gas-Discharge Systems: Experiment, Gas-Discharge: Theory, Semiconductors: Experiment, Semiconductors: Theory, Reaction-Diffusion Equations

Pu131: **Purwins (2007)**
solitary filaments and related DSs
summary - stressing that the formation of solitary filaments and related DSs in planar low temperature dc and ac gas-discharge systems is a generic phenomenon - stressing that in many respect DSs behave like particles - illustration of the formation of DSs in planar electrical transport systems on the basis of the 2-component reaction diffusion equation - considered experimentally observed phenomena.: e.g. isolated solitary filaments and related DSs, snaking, bifurcation from stationary to travelling solitaryfilaments and related DSs, mutual interaction of solitary filaments and related DSs with scattering, "molecule" formation, generation and annihilation as well as "many body systems" in the form of crystal-, liquid-, gas-like arrangements, domain structures and chains and nets - pointing out that the 3-component reaction-diffusion system seems to present a kind of normal form for the qualitative description of self-organized patterns in the discussed gas-discharge systems - listing of potential applications - see also: AC Gas-Discharge Systems: Experiment, Gas-Discharge: Theory, Reaction-Diffusion Equations

B. Quasi 2-dimensional dc systems

B. 4.1 General remarks

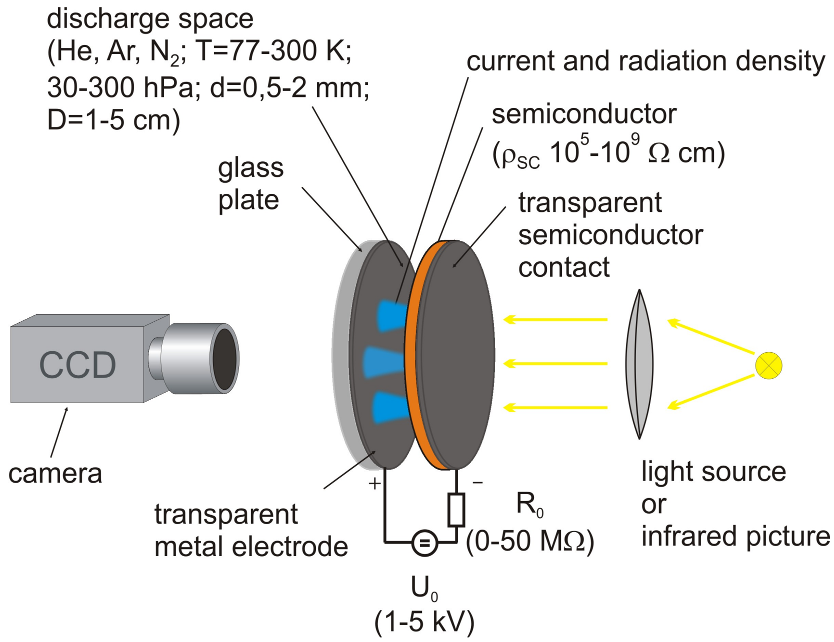

Fig. 4.10

In the experimental set-up fig. 4.10 patterns of interest show up in the luminescence radiation of the gas space in a plane parallel to the electrodes. Therefore this device we refer to as quasi 2-dimensional. The luminescence radiation is recorded through the transparent electrode and is proportional to the current in the gas to good approximation. The resistivity of the high ohmic layer can be controlled optically via the internal photo effect using an appropriate light source. In this way also self-organized patterns can be controlled opto-electronically. In the camera e.g. bright (dark) solitary filaments generate bright (dark) spots on a stationary dark (bright) background.

For modelling of the system fig. 4.10 and remarks concerning the interpretation of the observed LSs as DSs we refer to the notes made in relation to fig. 4.1. - The system fig. 4.10 is also the basis for an ultrafast device for the conversion of series of infrared images into the visible as is discussed in the chapter Application.

B. 4.2 Graphical representation of selected results

The following is a series of figures reflecting main results that have been obtained experimentally in relation to the investigation of quasi 2-dimensional dc gas-discharge systems fig. 4.10.

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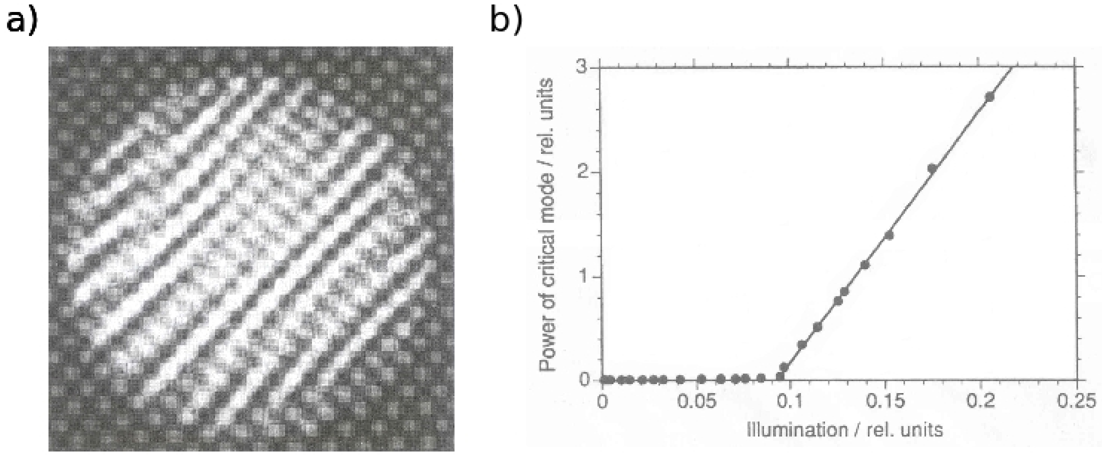

Fig. 4.11a,b

Experimentally observed self-organized periodic stripes observed in the quasi 2-dimensional dc gas-discharge system fig. 4.10 and supercritical bifurcation from a stationary homogeneous state (not displayed) to a stationary periodic stripe pattern (a). The spot pattern is an artefact. The square of the fundamental Fourier mode scales linearly with the bifurcation parameter as is expected theoretically for the supercritical Turing bifurcation (b). [Pu049] - compare to: experiment figs. 3.10, 4.2, 4.3, 4.13, 5.4; theory 9.9 - see also [I. Müller, „Dynamisches Verhalten in strukturbildenden planaren Gasentladungssystemen, Diplom-Arbeit, University of Münster (1996)]

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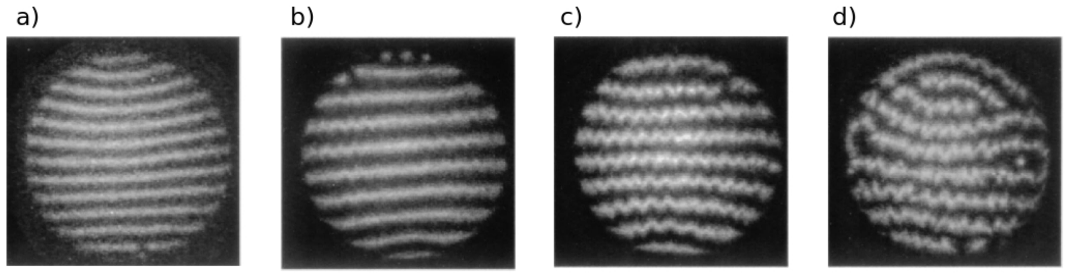

Fig. 4.12a-d

Snapshot of experimentally observed zigzag destabilization of a stationary periodic stripe pattern observed in the quasi 2-dimensional dc gas-discharge system fig. 4.10. The incoming light source intensity is increased from (a) to (d). [Pu056] - (for the destabilization of individual stripes see also [Pu073])] - see also [I. Müller, „Dynamisches Verhalten in strukturbildenden planaren Gasentladungssystemen, Diplom-Arbeit, University of Münster (1996)]

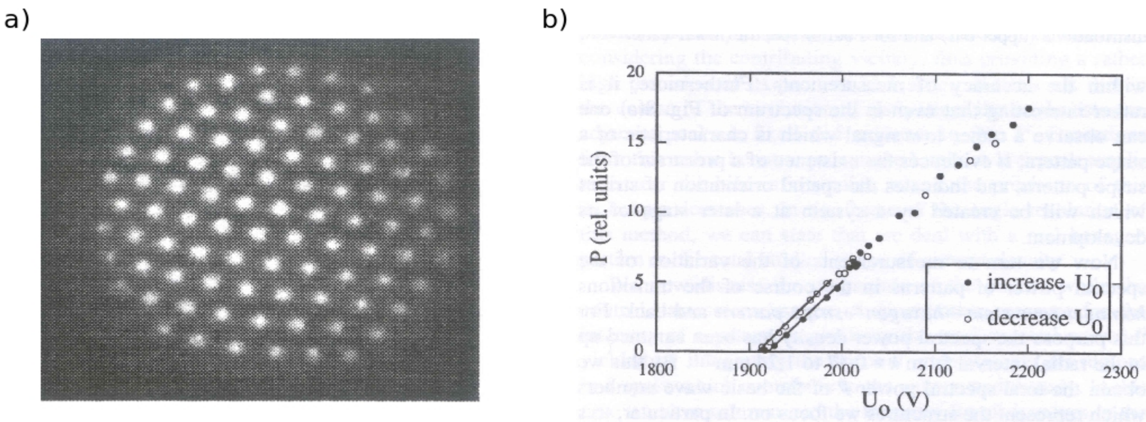

Fig. 4.13a,b

Experimentally observed self-organized pattern observed in the quasi 2-dimensional dc gas-discharge system fig. 4.10 exhibiting a bifurcation from a stationary homogeneous state (not displayed) to a stationary hexagonal pattern (a). The square of the fundamental Fourier mode scales linearly with the bifurcation parameter *U_0* though hysteresis cannot be excluded (b). [Pu063] - compare to: experiment figs. 3.10, 4.2, 4.3, 4.11, 5.4; theory 9.9 - see also [I. Müller, „Dynamisches Verhalten in strukturbildenden planaren Gasentladungssystemen, Diplom-Arbeit, University of Münster (1996); Pu049; Pu057: Pu063]

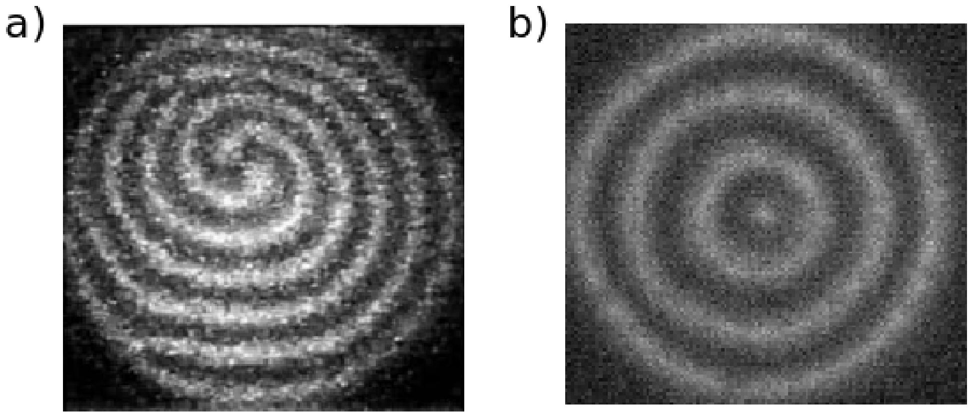

Fig. 4.14a,b

Snapshots of an experimental self-organized rotating and outrunning spiral pattern (a) and an outrunning target pattern (b) in the quasi 2-dimensional dc gas-discharge system fig. 4.10. [Pu061, Pu115] - compare to: experiment figs. 4.15, 5.6; theory 9.9 - see also [I. Müller, „Dynamisches Verhalten in strukturbildenden planaren Gasentladungs-systemen, Diplom-Arbeit, University of Münster (1996)]

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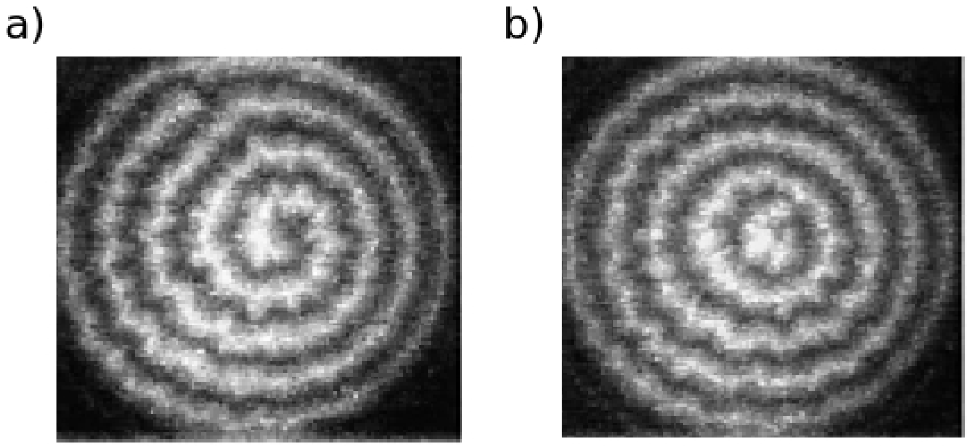

Fig. 4.15a,b

Snapshots of experimentally observed zigzag destabilized pattern observed in the quasi 2-dimensional dc gas-discharge system fig. 4.10: rotating and outrunning spiral (a) and outrunning target pattern (b). [Pu061] - compare to: experiment figs. 4.14, 5.6

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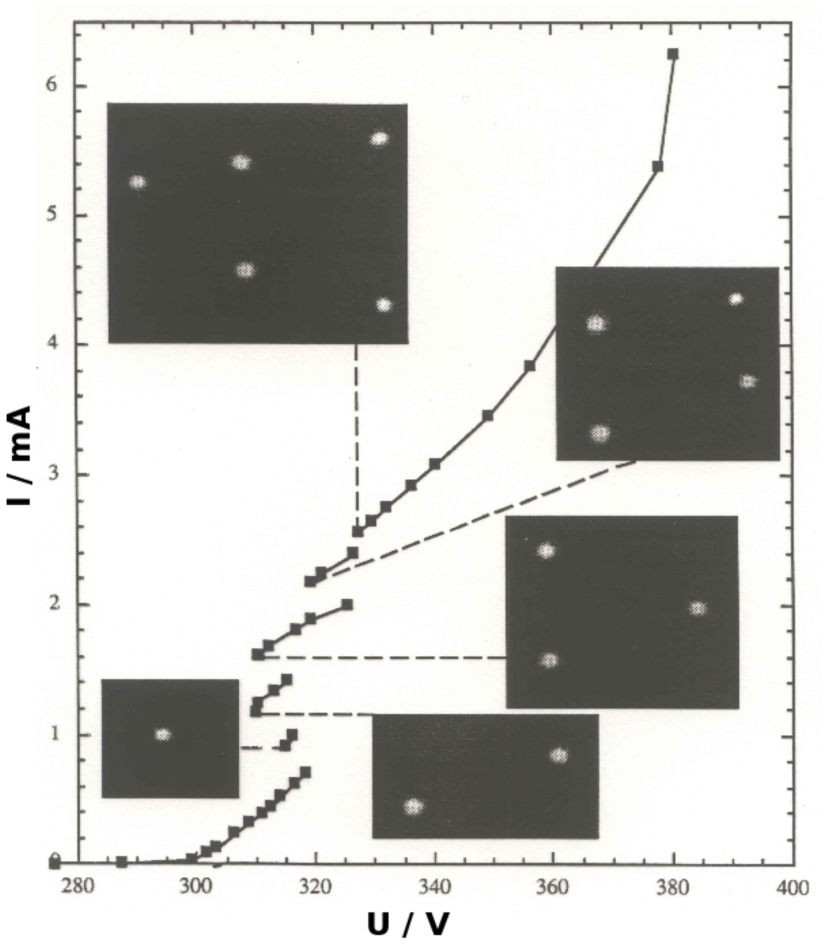

Fig. 4.16

Experimentally observed cascades of stationary filaments in the quasi 2-dimensional dc gas-discharge system fig. 4.10: When increasing the driving voltage U_0 an increasing number of stationary filaments is observed. At the same time any generation of filaments is accompanied by a jump in the characteristic showing the total current I through the device in dependence of the voltage drop $U = (U_0 - R_0 I)$ [E. Ammelt, "Untersuchungen zur Strukturbildung in planaren Gasentladungssystemen mit bildverarbeitenden Methoden", Thesis, University of Münster (1995); Pu131] - compare to: experiment figs. 3.12, 4.5, 4.6, 5.7, 5.18, 7.3, 7.10; theory figs. 3.12, 9.6, 9.10

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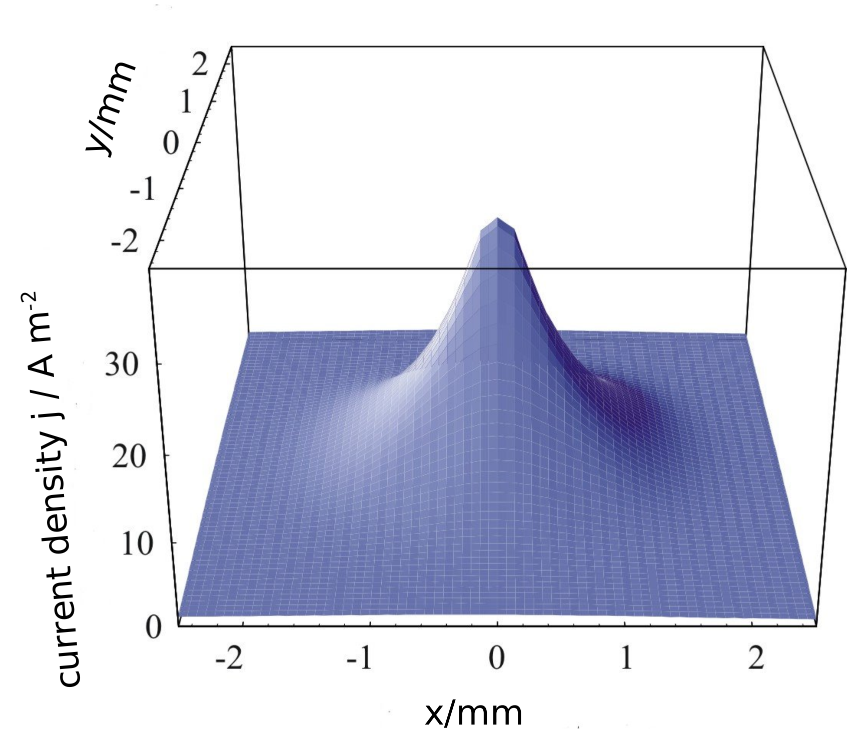
non-oscillatory tails



oscillatory tails

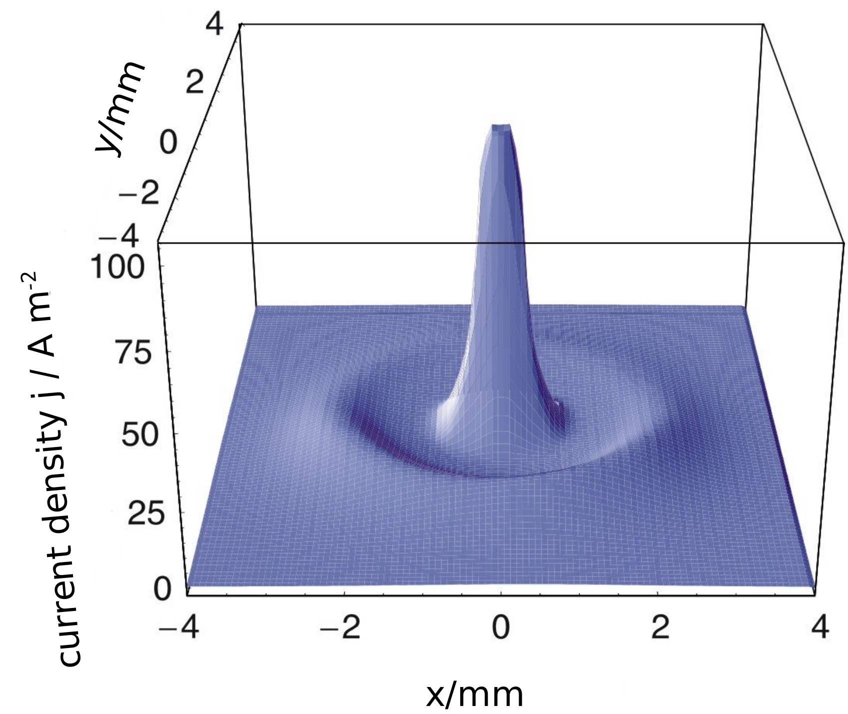


Fig. 4.17

Fig. 4.17

Experimentally observed two kinds of filaments in the quasi 2-dimensional dc gas-discharge system fig. 4.10: Depending on the chosen parameters filaments with non-oscillatory and with oscillatory tails can be found. In particular the latter give rise to interesting interaction phenomena. The full experimental domain is much larger than the observed diameter of the filaments. [Pu110] - compare to: experiment figs. 3.14, 4.19, 4.20, 4.21, 5.8; 5.12; theory 9.3, 9.11, 9.12, 9.18, 9.19, 9.20, 9.30

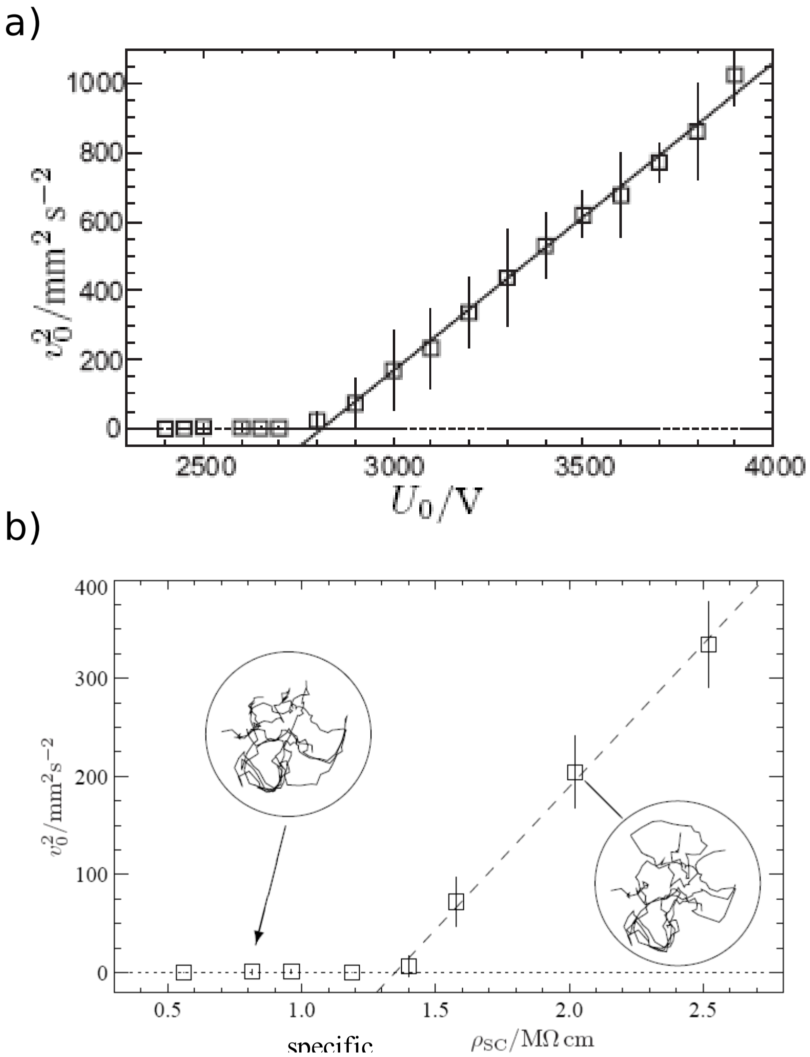


Fig. 4.18a,b

Experimentally observed supercritical bifurcation from a stationary to a travelling filament in the quasi 2-dimensional dc gas-discharge system fig. 4.10. The experimental points depict the square of the intrinsic (deterministic) speed v_0 as a function of the bifurcation parameters being the external driving voltage U_0 [Pu113] (a) and the specific resistivity of the semiconductor layer ρ_{SC} (b) [Pu098; Pu099]. In (b) we also display typical trajectories of individual filaments with vanishing (left) and non- vanishing intrinsic speed (right). Beyond the bifurcation point the square if the speed v_0 scales linearly with U_0 and ρ_{SC} as expected from theory and equation (10) of the chapter Reaction-Diffusion Equations. v_0 is evaluated from noisy trajectories of individual filaments using a stochastic data analysis method that has been developed in [Pu098, Pu099, Pu132] (see also chapter Reaction-Diffusion Equations) - compare to: experiment fig. 5.9; theory figs. 9.1, 9.13, 9.14, 9.21

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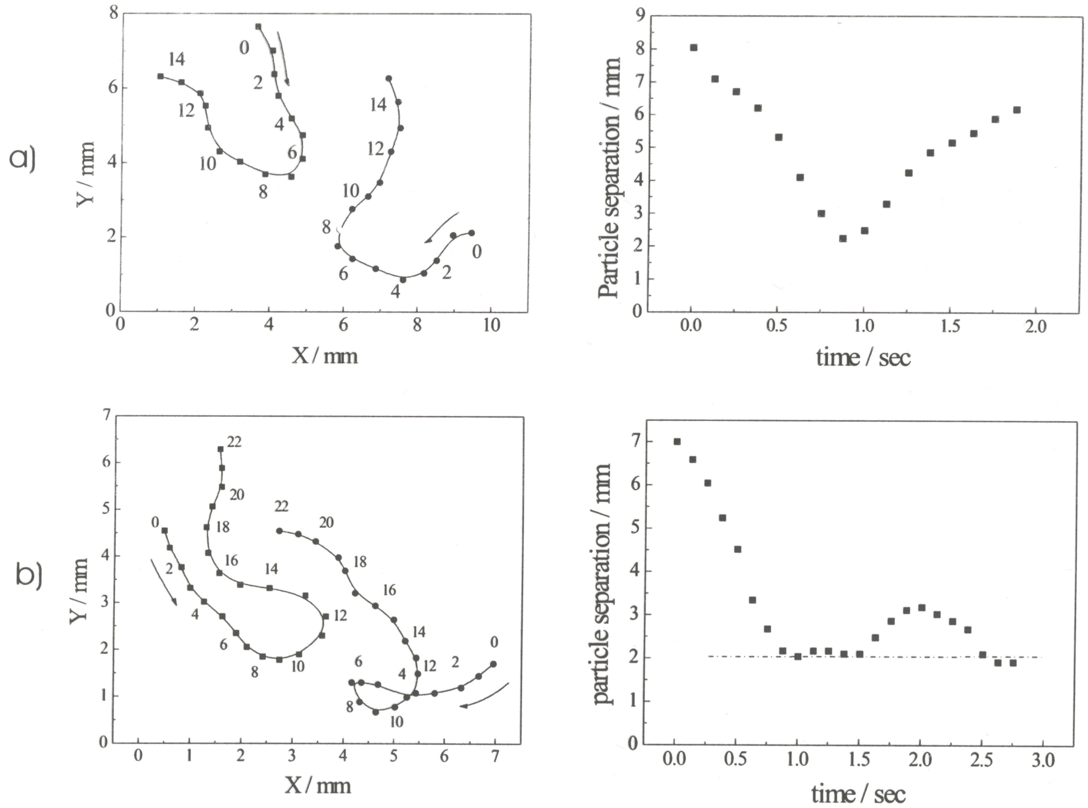

Fig. 4.19a,b

Experimentally observed interaction of filaments in the quasi 2-dimensional dc gas-discharge system fig. 4.10: Trajectories of two filaments (left) and inter-filamentary distance (right) in the case of a scattering event (a) and the formation of a bound state (molecule) (b) . [Pu081] - compare to: experiment figs. 3.13, 3.14, 4.7, 5.8, 5.12; theory figs. 9.8, 9.12, 9.17, 9.18, 9.19, 9.20, 9.29, 9.30

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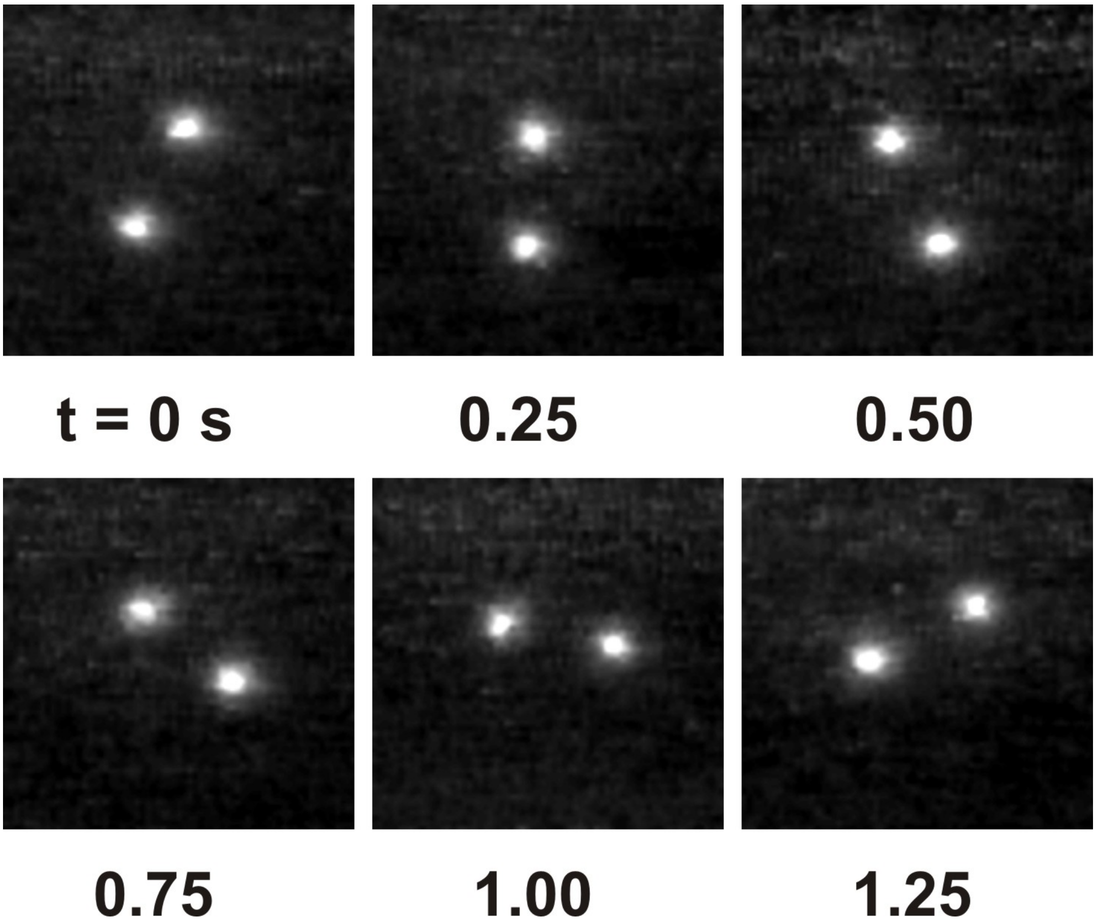


Fig. 4.20

Experimentally observed rotating cluster of two filaments in the quasi 2-dimensional dc gas-discharge system fig. 4.10: The cluster ("molecule") rotates with constant angular velocity. [Pu109] - compare to: experiement figs. 3.14, 4.7, 4.19, 5.8, 5.12; theory 9.3, 9.12, 9.18, 9.19, 9.20, 9.30

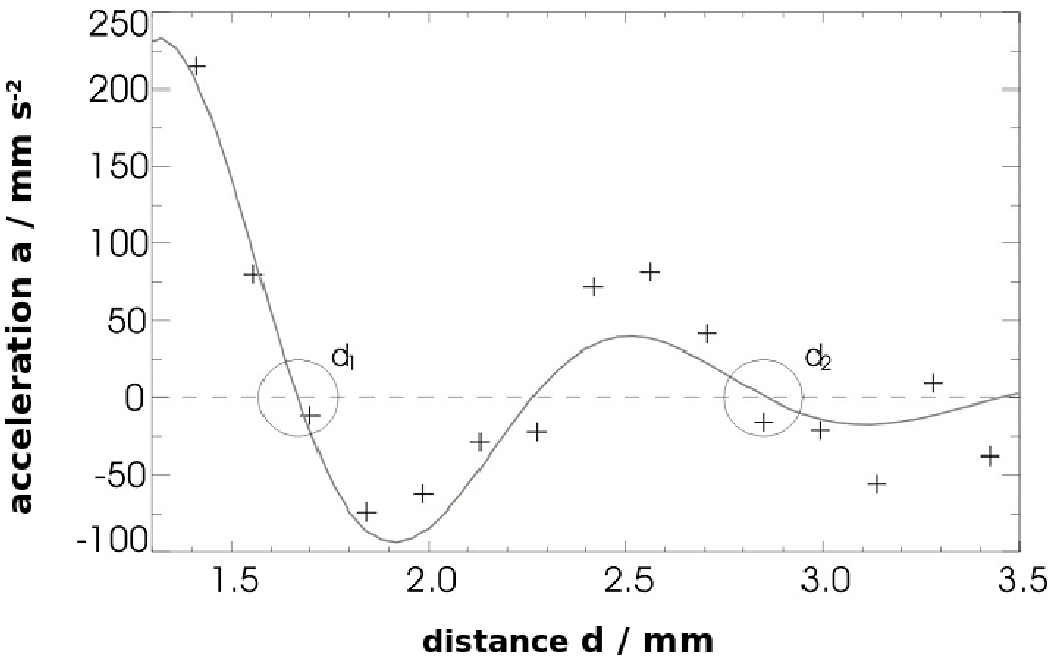
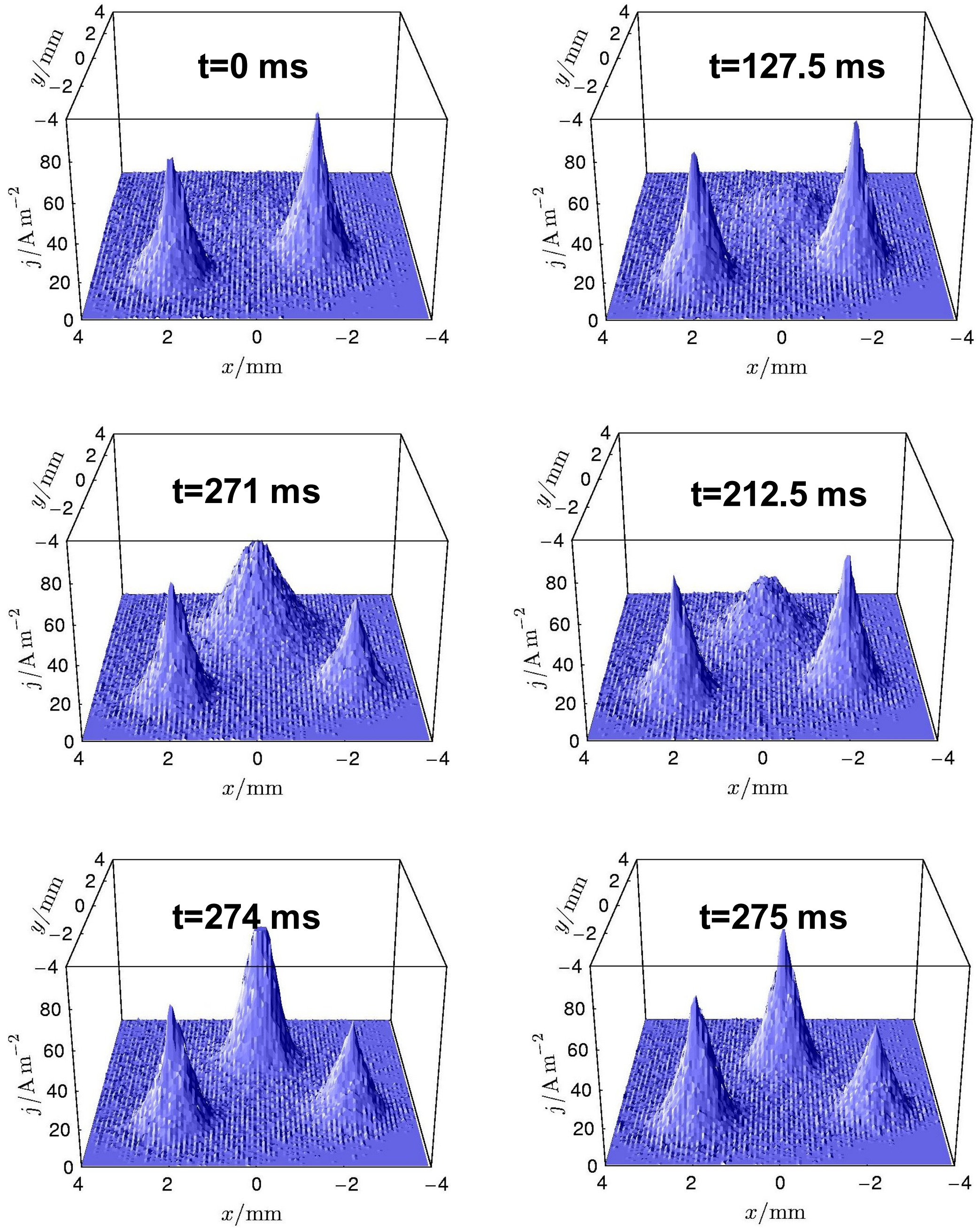


Fig. 4.21

Experimentally determined law for the weak mutual interaction of filaments in the quasi 2-dimensional dc gas-discharge system fig. 4.10: The acceleration depicted by crosses corresponds to the function $F(|p_i - p_j|)$ in the particle description of DSs with oscillatory tails given by the equation (4-7) of the chapter Reaction-Diffusion Equations. The continuous curve is a fit to a damped cosine function, a shape that typically results from corresponding numerical solutions of the FHN equation (1-3) of the chapter Reaction-Diffusion Equations. The circles indicate stable lock-in positions for a second filament. The depicted interaction law corresponds to a DS with oscillatory tails. The deterministic acceleration of the filaments has been evaluated from noisy trajectories of individual filaments by a newly developed stochastic data analysis method. [Pu110] - compare to: experiment figs. 3.14, 4.17, 5.15, ; theory figs. 9.3, 9.12, 9.18, 9.19, 9.20, 9.24, 9.33

A)



t=0 ms
t=127.5 ms
t=271 ms
t=212.5 ms
t=274 ms
t=275 ms
y/mm
$j/\mathrm{A\,m^{-2}}$
x/mm

Fig. 4.22A

B)

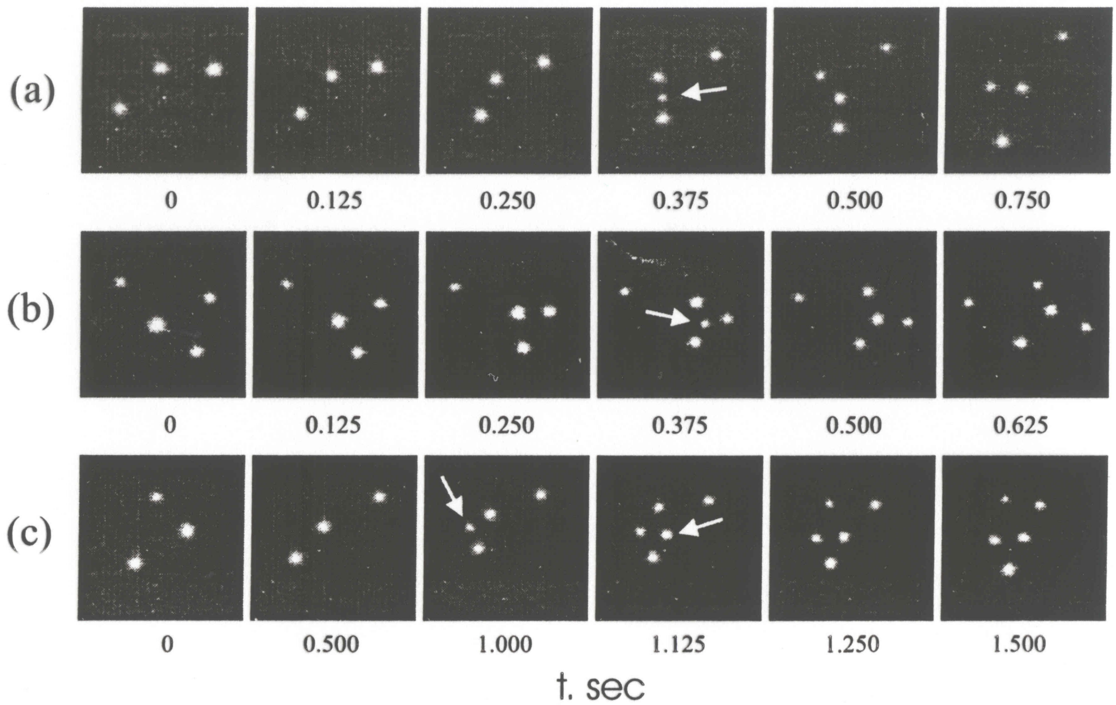


Fig. 4.22B

Fig. 4.22A,B

Experimentally observed generation of a filament in the quasi 2-dimensional dc gas-discharge system fig. 4.10: In (A) in the course of the collision of two propagating filaments a third one is generated [Pu118]. In (B) from (a – c) various generation processes are observed in the course of time [Pu081]. - compare to: experiment figs. 4.7, 5.13, ; theory figs. 9.23, 9.34 - see also [see also J. C. Strümpel, „Experimentelle Untersuchung der raumzeitlichen Strukturierung in einem planaren Gasentladungssystem", Thesis, University of Münster (2001); Pu080; Pu081; Pu124]

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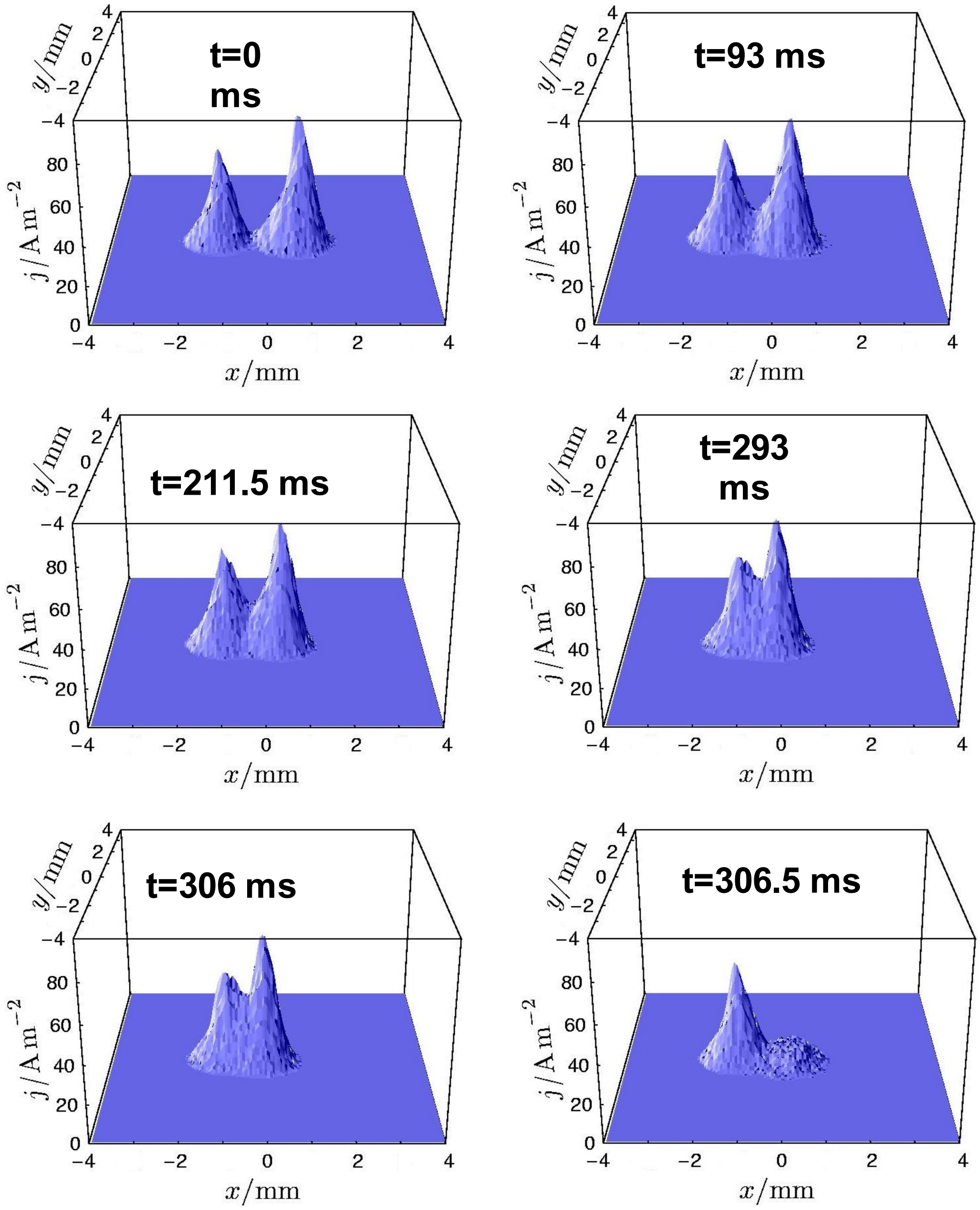

Fig. 4.23

Experimentally observed annihilation of a filament in the quasi 2-dimensional dc gas-discharge system fig. 4.10: In the course of the collision of two propagating filaments one of them disappears. [Pu118] - compare to: experiment figs. 4.7, 5.13,; theory figs. 9.22, 9.31, 9.34 - see also [J. C. Strümpel, „Experimentelle Untersuchung der raumzeitlichen Strukturierung in einem planaren Gasentladungssystem", Thesis, University of Münster (2001); Pu080]

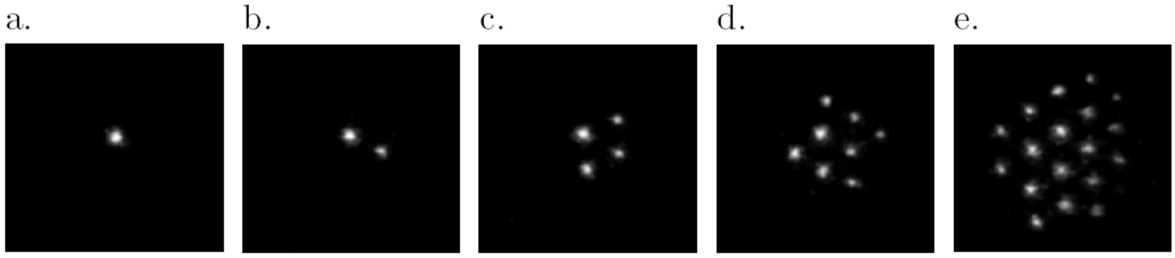

Fig. 4.24a-e

Experimentally observed self-completion of filaments in the quasi 2-dimensional dc gas-discharge system fig. 4.10: In the course of time near to an existing filament an increasing number of filaments is generated at well defined distance to adjacent filaments until the plain is fully covered with a hexagonal pattern made of individual filaments. [Ammelt, Astrov, Purwins, unpublished] - compare to: theory figs. 9.24, 9.33

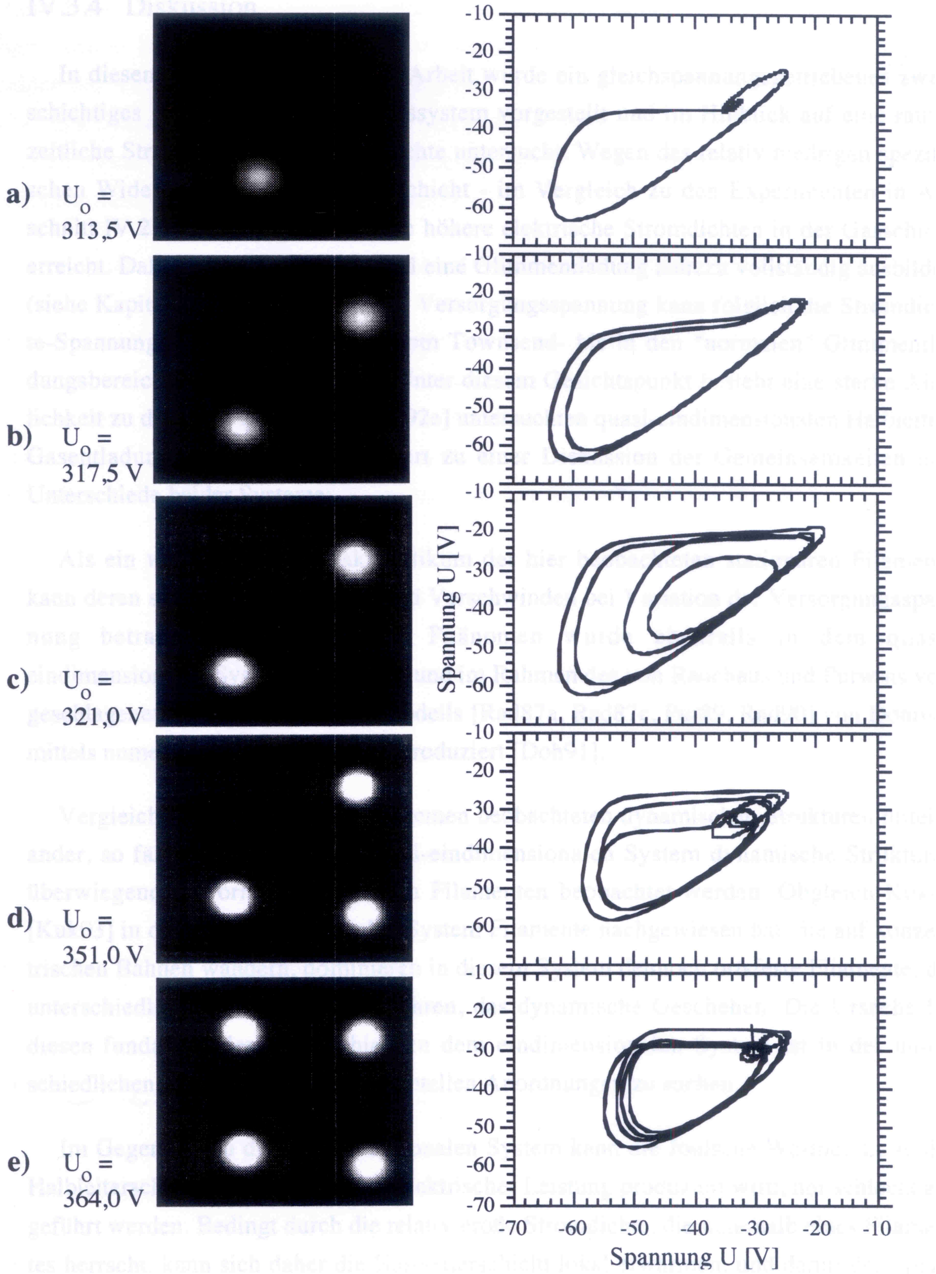

Fig. 4.25a-e

Experimentally observed oscillating solitary filaments in the quasi 2-dimensional dc gas-discharge system fig. 4.10: The number of filaments increases with the driving voltage U_0 that increases from (a) to (e) (left hand row). The individual filaments stay at the same position in the course of time being switched on and off subsequently in a periodic manner as can be seen from the corresponding return maps (right hand row). - [E. Ammelt, "Untersuchungen zur Strukturbildung in planaren Gasentladungssystemen mit bildverarbeitenden Methoden", Thesis, University of Münster (1995)]

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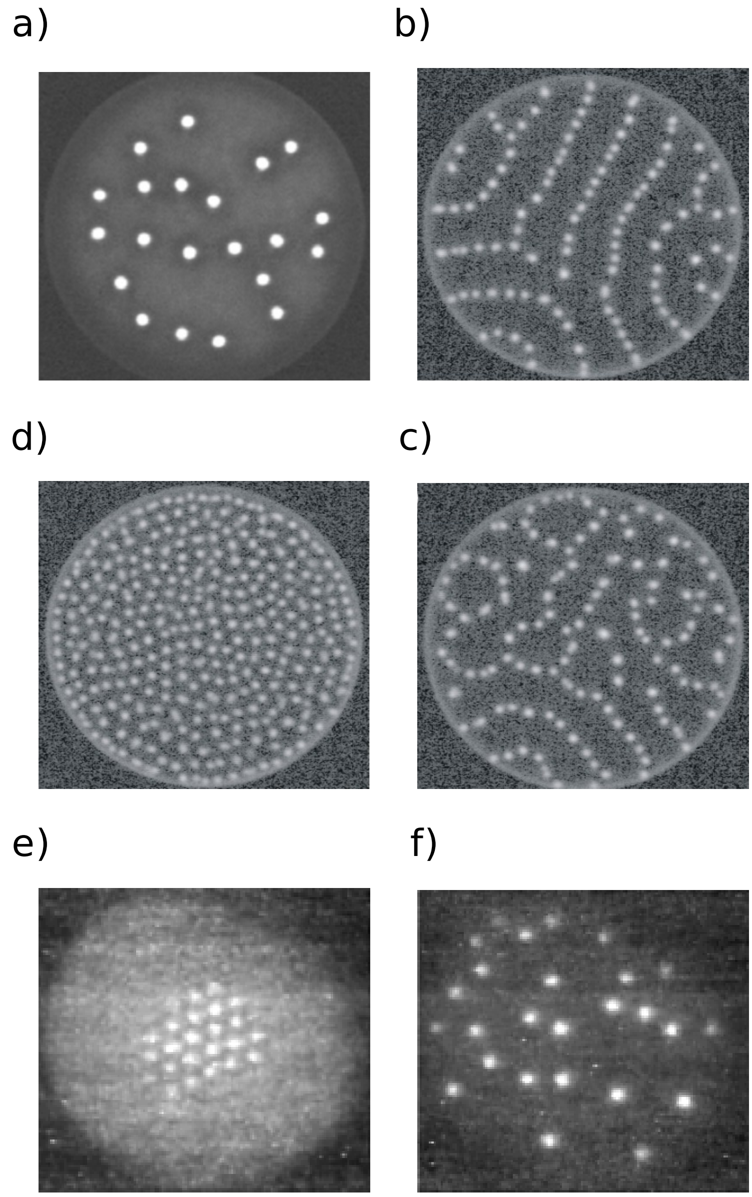

Fig. 4.26a-f

Experimentally observed many filament patterns in the system fig. 4.10: "Gas" (a) [Pu080], dynamical chains (b) [Pu080] , dynamical nets (c) [Pu080], "liquid" (d) [Pu080], "crystal" (e) [Pu081] and indication of the coexistence of a crystal- and a gas-like phase (f) [Pu081] - compare to: experiment figs. 4.7, 5.7, 5.15, 5.18; theory figs. 9.36 - see also [Pu089; Pu102; Pu115]

B. 4.3 Listing of main results

With respect to the abbreviations used in the following listing of observed phenomena we refer to the Introduction.

Pu049: **Astrov, Ammelt, Terperick, Purwins (1996)**

stripes in R^2

exp: 2-d-dc-GDS, $R_0 \neq 0$ - stat periodic stripes; corresponding defect structures

hexagons in R^2

exp: 2-d-dc-GD, $R_0 \neq 0$ - stat hexagons; corresponding defect structures

bifurcation

exp: 2-d-dc-GDS, $R_0 \neq 0$ - (stat hom) ↔ (stat hex) ↔ (non stat)**;** (stat hom) ↔ (stat hex) ↔ (stat periodic stipes) ↔ (non-stat pattern); (stat hom) ↔ (stat periodic stripes) ↔ (non-stat pattern); (stat hom) ↔ (stat periodic stripes), supercritical Turing with correct scaling law

experimental detection of a supercritical Turing bifurcation with correct scaling law - [Pu049] together with [E. Ammelt, "Untersuchungen zur Strukturbildung in planaren Gasentladungssystemen mit bildverarbeitenden Methoden", Thesis, University of Münster (1995)] is the starting point for a unique observation of a large variety of patterns in quasi 2-dimensional dc gas-discharge systems

Pu051: **Ammelt, Astrov, Purwins (1996)**

summary of parts of the works [Pu049]

Pu056: **Astrov, Ammelt, Purwins (1997)**

many body LS- (DS-)systems

exp: 2d-dc-GDS, $R_0 \neq 0$ - almost equidistant LSs in the discharge plane - almost equidistant fs arranged on a zigzag line, the zigzag modulation travels along the individual stripes while there is a continuous rearrangement of DS including a change of direction of propagation

stripes in R^2

exp: 2-d-dc-GDS, $R_0 \neq 0$ - stat periodic stripes as high amplitude structure

miscellaneous patterns

exp: 2d-dc-GDS, $R_0 \neq 0$ - a zigzag modulation travels along the individual stripes of the originally stationary periodic stripe pattern

bifurcation

exp: 2d-dc-GDS, $R_0 \neq 0$ - bif with increasing overall current: (stat hom) ↔ (transition state possibly consisting of LS) ↔ (stat equidistant stripes) ↔ (zigzag modulation travels along the individual stripes of the originally stationary periodic stripe pattern) ↔ (defect structure of the former)

exp: 2d-dc-GDS, $R_0 \neq 0$, definition of an elongated, but narrow rectangular domain - bif with increasing illumination: (equidistant fs arranged on a straight line) ↔ (contunuous straight line) ↔ (almost zigzag destabilized straight line) ↔ (tendency to equidistant fs arranged on a zigzag line)

experimental detection of a new kind of zigzag bifurcation in quasi 2-dimensional dc gas-discharge systems

Pu057: Ammelt, Astrov, Purwins (1997)

stripes in R^2

exp: 2-d-dc-GDS, $R_0 \neq 0$ - periodic stat, drifting stripes

hexagons in R^2

exp: 2-d-dc-GDS, $R_0 \neq 0$ - stat periodic hex

bifurcation of LSs

exp: 2-d-dc-GD, $R_0 \neq 0$ - (stat hom) ↔ (stat hex) ↔ (stat periodic stripes or some non-stationary structure); (stat hom) ↔ (stat periodic stripes) ↔ (some non-stationary structure); - (stat hom) ↔ (drifting periodic striper) ↔ (some non-stationary structure), (stat hom) ↔ (drifting periodic stripe) is supercritical with the approximate scaling law expected for a Turing bif

experimental detection of various kinds of bifurcations

Pu061: Astrov, Müller, Ammelt, Purwins (1998)

isolated travelling fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - indication of trav fs

isolated breathing fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - fs oscillating between spherical and star-like symmetry of the cross section

excitation of internal degrees of freedom of fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - indication of trav fs, breath fs; formation of fs with star-like fs

generation, annihilation of fs: due to interaction

exp: 2d-dc-GDS, $R_0 \neq 0$ - gen at boundary, annni by collision

many f-systems

exp: 2d-dc-GDS, $R_0 \neq 0$ - many fs: gas-like behaviour with gen at boundary and anni by collision; at the same time observation of excitation of internal degrees of freedom accompanied by a kind of breathing and star-like symmetry of the cross section - targets and stripes made of fs

stripes in R^2

exp: 2d-dc-GDS, $R_0 \neq 0$ - low amplitude stripe and corresponding defect structure;

hexagons in R^2

exp: 2d-dc-GDS, $R_0 \neq 0$ - low amplitude non-stationary hex and corresponding defect structure; hex made of star-like DSs

rotating spirals and targets in R^2

exp: 2d-dc-GDS, $R_0 \neq 0$ - rotating spirals with complex tip dynamics; target patterns, zigzag destabilization of spirals and targets; in the course of time: transition between zigzag destabilized spirals and targets

bifurcation
exp: 2-d-dc-GD, $R_0 \neq 0$S - (hexagons) ↔ (stripes) ↔ (stripes with defects) ↔ (rotating spirals) - (spiral defect chaos); (many trav fs with gen and anni as well as with breath star-like f cross section and fs almost arranged in a hex pattern) ↔ (partial arrangement fs with star-like cross sections on segment of spirals) ↔ (rotating spiral with arms exhibiting zigzag form and consisiting of fs with star-like cross section);
experimental detection of rotating spirals and target patterns in gas-discharge - experimental detection of the excitation of internal degrees of freedom of solitary filaments and related DSs - experimental detection of superstructures e.g. in the form spirals and targets made of solitary filaments

Pu063: **Ammelt, Astrov, Purwins (1998)**
stripes in R^2
exp: 2d-dc-GDS, $R_0 \neq 0$ - slightly drifting periodic stripes
theo: 2-k - stat stripes
hexagons in R^2
exp: 2d-dc-GDS, $R_0 \neq 0$ - slightly drifting hex pattern
theo: 2-k - stat hex pattern; hex defect structures
bifurcation
exp: 2d-dc-GDS, $R_0 \neq 0$ - (hom stat) ↔ (hex) ↔ (stipes), (hom stat) ↔ (hex) subcritical; (hom stat) ↔ (stipes), possibly supercritical Turing
theo: 2-k - (stat hom) ↔ (stat hex) ↔ (stat stipes)
experimental proof for expected bifurcations from the stationary homogeneous to a small amplitude stripe or hexagonal pattern - see also: Reaction-Diffusion Equations

Pu073: **Strümpel, Astrov, Ammelt, Purwins (2000)**
detailed investigation of the new kind of bifurcation being reported in [Pu056]: determination of the speed of propagation of the zigzag modulation

Pu075: **Strümpel, Astrov, Ammelt, Purwins (2000)**
destabilization of the stationary homogeneous state in a quasi 2-dimensional dc gas-discharge system by a subcritical Hopf bifurcation: homogeneous oscillations, generation of oscillating sub-domains by external control, study of the interaction of the resulting domains

Pu078: **Purwins, Astrov, Brauer (2001)**
summary - experimental observation of solitary filament and related DSs based and other patterns in planar gas-discharge systems observed in previous work

Pu080: **Strümpel, Purwins, Astrov (2001)**
isolated stationary and travelling fs
exp: 2d-dc-GDS, $R_0 \neq 0$ - stat, trav fs; individual fs are switched on and off on a short time scale practically having not changed position, no temporal correlation foradjacent DS switching
splitting of fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - splitting; for short time some behaviour of individual fs in all cases: see isolated fs

interaction of fs: formation of molecules

exp: 2d-dc-GDS, $R_0 \neq 0$ - see entry "many f-systems"

generation, annihilation of fs: due to interaction or spontaneously

exp: 2d-dc-GDS, $R_0 \neq 0$ - gen by splitting; an spontaneously

many f-systems

exp: 2d-dc-GDS, $R_0 \neq 0$ - gas-like behaviour of fs with fluctuating number; dynamical chains being oriented vertical to the boundary and approximately parallel to each other; dynamical nets made of fs chains; liquid-like behaviour of fs with fluctuating number; for short time some behaviour of individual fs in all cases: see isolated fs

bifurcation of many f- systems

exp: 2d-dc-GDS, $R_0 \neq 0$ - essentially: (gas-like behaviour) ↔ (dynamical chains) ↔ (dynamical nets) ↔(liquid-like Behaviour

detection of self-organized chains and nets with relatively slow dynamics made of solitary filament and related DSs with fast stochastic switching dynamics

Pu081: Purwins, Astrov (2001)

isolated stationary and travelling fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - trav fs

isolated stationary, travelling and rotating fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - trav molecules

splitting of fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - splitting

interaction of fs: scattering

exp: 2d-dc-GDS, $R_0 \neq 0$ - scattering

interaction of fs: formation of molecules

exp: 2d-dc-GDS, $R_0 \neq 0$ - trav molecules

generation, annihilation of fs : due to interaction

exp: 2d-dc-GDS, $R_0 \neq 0$ - gen by splitting; gen by collision; annni by fusion; an by interaction with the boundary

many f-systems

exp: 2d-dc-GDS, $R_0 \neq 0$ - hex pattern with tendency to form regularly arranged fs, crystalline-like state **;** hex pattern based on fs with defects being in dynamic equilibrium with a gas-like state; gas-like state consisting of regularly arranged fs

bifurcation of fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - essentially: (hex Turing pattern) ↔ (hex pattern with tendency to form regularly arranged fs, crystalline-like state) ↔ (hex pattern consisting of fs with defects being in dynamic equilibrium with a gas-like state) ↔ (gas-like state consisting of trav fs)

experimental detection of various new phenomena related to solitary filament and related DSs - scattering, molecule formation, generation, annihilation - crystalline- and gas-like states being in dynamical equilibrium, similar to a first order phase transition

Pu083: **Purwins, Astrov, Brauer, Bode (2001)**
summary - experimental observation of solitary filaments and related DSs based on static and dynamic patterns in planar gas-discharge systems observed in previous work - comparison of the experimental results with solutions of the 2- and 3-component reaction-diffusion model - see also: Reaction-Diffusion Equations

Pu089: **Strümpel, Astrov, Purwins (2002)**
isolated stationary and travelling fs
exp: 2d-dc-GDS, $R_0 \neq 0$ - single subharmonically oscillating fs on an oscillating background with rational frequency relation with respect to the background; in the presence of more than one f they may have different frequency relations with respect to the background; individual fs being switched on and off statistically, as mentioned in [Pu080]
many f-systems
exp: 2d-dc-GDS, $R_0 \neq 0$ - gas-like pattern with complex f dynamics as described in [Pu80]
miscellaneous patterns
exp: 2d-dc-GDS, $R_0 \neq 0$ - periodically oscillating hom state; switching off and on of DSs on a periodically oscillating background with rational subharmonic frequency relations with respect to the background; irregular switching on and off of fs as described in [Pu80]
bifurcation of fs including snaking
exp: 2d-dc-GDS, $R_0 \neq 0$ - bif with increasing driving voltage: (stat hom) ↔ (periodically oscillating hom) ↔ (fs on the periodically oscillating background with rational subharmonic frequency relations to the background) ↔ (transition to increasingly irregular switching on and off of fs as described in [Pu80])
detection of DSs being switched off and being observed on an oscillating background - the background oscillation can serve as driver for the DS oscillations and frequency locking can be observed

Pu095: **Astrov, Purwins (2002)**
experimental proof for the previously experimentally investigated planar dc gas-discharge systems with GaAs layers [Pu089]: the semiconductor and not the gas is the active medium in this case - opening of a new technique to measure pattern formation in planar semiconductor wavers via associated gas-discharge in a device of the kind fig. 4.10; advantage: by orders of magnitude higher luminescence radiation density

Pu097: **Gurevich, Moskalenko, Zanin, Astrov, Purwins (2003)**
more details on the proof for the previously experimentally investigated planar gas-discharge systems with GaAs layers, that the semiconductor and not the gas is the active medium (see also [Pu095]) - detection of a curved "arm" rotating with one end being fixed in the centre

Pu098: **Bödeker, Röttger, Liehr, Frank, Friedrich, Purwins (2003)**

Pu099: **Liehr, Bödeker, Röttger, Frank, Friedrich, Purwins (2003)**

isolated stationary and travelling fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - intrinsically stat, intrinsically trav fs with superimposed noise; experimental determination of stochastic trajectories of individual fs

theo: 3-k, R^2 - stat, trav fs

bifurcation of fs: travelling bif

exp: 2d-dc-GDS, $R_0 \neq 0$ - (stat f) ↔ (trav f), trav bif

theo: 3-k, R^2 - (stat f) ↔ (trav f), trav bif

application of the particle concept being based on the 3-component reaction-diffusion equation near to the bifurcation from the intrinsically stationary to the intrinsically travelling DS (see [Pu084]) - experimental determination of trajectories of individual solitary filament and related DSs - development of a new stochastic data analysis method to extract the intrinsic speed from the experimentally determined stochastic trajectories of DSs - first experimental determination of the supercritical bifurcation from a stationary to a travelling solitary filament and related DS - good agreement between the theoretical and the experimental scaling law for the speed in the vicinity of the travelling bifurcation point - see also: Reaction-Diffusion Equations

Pu102: **Gurevich, Astrov, Purwins (2003)**

experimental material also contained in [Pu080. Pu095, Pu097]

Pu107: **Gurevich, Liehr, Amiranashvili, Purwins (2004)**

justification of the third component in the 3-component reaction-diffusion system: by comparing experimental results for the surface charge and related experimental properties with estimates from theory it is demonstrated that it is suggestive to consider the surface charge of the (high ohmic layer)-(gas dischargespace)-interface as the second inhibitor that has been introduced in [Pu053] when setting up the 3-component reaction-diffusion system

Pu109: **Liehr, Moskalenko, Astrov, Bode, Purwins (2004)**

isolated stationary and travelling fs

theo: 3-k, R^2 - stat, trav fs

interaction of fs: formation of molecules

exp: 2d-dc-GDS, $R_0 \neq 0$ - rotating 2-f (molecule)

theo: 3-k, R^2 - stat, rotating 2-f (molecule)

bifurcation of fs

theo: 3-k, R^2 - (stat2-f) ↔ (rotating 2-f)

experimental detection of a rotating pair of solitary filaments and related DSs - description in terms of the 3-component reaction-diffusion equation - see also: Reaction-Diffusion Equations

Pu110: **Bödeker, Liehr, Frank, Friedrich, Purwins (2004)**

isolated stationary and travelling fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - experimental determination of the stochastic trajectories of two interacting fs

theo: 3-k, R^2 - stat, trav DSs

interaction of fs: scattering and reflection

exp: 2d-dc-GDS, $R_0 \neq 0$ - two stochastically trajectorie of fs interacting with each other

applying the particle concept being based on the 3-component reaction-diffusion equation near to the bifurcation from the intrinsically stationary to the intrinsically travelling DS - experimental determination of trajectories of individual solitary filament and related DSs - development of a new stochastic data analysis method to extract from the experimentally determined stochastic trajectories the interaction law - first experimental determination of the interaction law of solitary filament and related DSs - see also: Reaction-Diffusion Equations

Pu113: **Gurevich, Bödeker, Moskalenko, Liehr, Purwins (2004)**

isolated stationary and travelling fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - stat, trav fs; experimental determination of the stochastic trajectories of isolated fs

theo: 3k, R^2 - stat, trav f

bifurcation of fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - (stat f) ↔ (trav f), supercritical with correct scaling law

theo: 3k, R^2 - (stat f) ↔ (trav f), supercritical

determination of the intrinsic speed of an isolated DS from its stochastic trajectory by following the procedure of [Pu098, Pu099] - supercritical travelling bifurcation with correct scaling law - in contrast to the case of [Pu098, Pu099] the change of shape of the DS is essential for the bifurcation - see also: Reaction-Diffusion Equations

Pu114: **Purwins, Bödeker, Liehr (2005)**

summary - experimental observation of solitary filaments and related DSs in quasi 2-dimensional planar dc gas-discharge systems observed in previous work - comparison of the experimental results with solutions of the 2- and 3-component reaction-diffusion model equation - see also: Reaction-Diffusion Equations

Pu115: **Gurevich, Astrov, Purwins (2005)**

isolated stationary and travelling fs

exp: 2d-dc-GDS, $R_0 \neq 0$ - ordinary fs; fs with frayedtails

stripes in R^2

exp: 2d-dc-GDS, $R_0 \neq 0$ - periodic stripes; individually curved propagating stripes

rotating spirals and targets in R^2

exp: 2d-dc-GDS, $R_0 \neq 0$ - rotating spirals; expanding target patterns

many body f-systems

exp: 2d-dc-GDS, $R_0 \neq 0$ - liquid and gas-like phase made of fs; chains made of DSs

bifurcation

exp: 2d-dc-GDS, $R_0 \neq 0$ - essentially: (liquid-like phase made of fs) ↔ (mixture of liquid-like phase made of fs and periodic stripes) ↔ (periodic stripes); (gas-like phase made of fs) ↔ (expanding target pattern) ↔ (rotating spiral) ↔ (isolated fs with frayed tails); (individual curved stripes) ↔ (gas-like phase made of fs) ↔ (chains)

investigation of the mechanism of pattern formation: depending on experimental conditions the semiconductor, the gas layer or both layers can act as active medium - rotating spirals and expanding targets

Pu116: **Gurevich, Amiranashvili, Purwins (2005)**
repetition of the experiments of Nasuno, Chaos 13, pp. 1010-1013 (2003) with two metallic electrodes - it can be proven that the multi-spot patterns observed in planar gas-discharge systems with purely metallic electrodes are due to the observation at long exposer time: high temporal resolution reveals that always a single spot shows up at a given moment of time

Pu118: **Purwins, Bödeker, Liehr (2005)**
review of previous works on DSs in reaction diffusion systems - mechanisms of pattern formation in 2-k systems: Turing patterns, localized structures, activator-inhibitor principle - derivation of the 2- and 3-component reaction-diffusion equation by starting from an electronic equivalent circuit - numerical solutions of the 3-component reaction-diffusion equation for isolated DS: DSs with non-oscillatory and oscillatory tails - numerical solutions of the 3-component reaction-diffusion equation for two interacting DSs: scattering, formation of rotating molecules, annihilation, generation - analytical treatment of the 3-component reaction-diffusion equation: normal form for the drift bifurcation, reduction of the field equation to a particle equation for a single particle and for mutually interacting particles, calculation of the particle interaction law - numerical and analytical treatment: rotating molecules in R^3 propagating along the axis of rotation - experimental results on solitary filament and related DSs in dc gas-discharge: isolated objects with non-oscillatory and oscillatory tails, drift bifurcation, interaction law, generation and annihilation - see also: Electrical Networks: Experiment and Theory, Reaction-Diffusion Equations

Pu122: **Gurevich, Raizer, Purwins (2006)**
experimental investigation of the stability range of self-organized homogenous oscillations in the quasi 2-dimensionl dc gas-discharge

Pu124: **Astrov, Purwins (2006)**
isolated stationary and travelling fs
exp: 2d-dc-GDS- stat, trav f
splitting of fs
exp: 2d-dc-GDS- fixed parameters: splitting of a stochastically moving fs ; increasing the driving voltage: splitting of a stat f, strong temporal fluctuations in the vicinity of the parameter value corresponding to splitting; similarities to 1d-dc-GDS discussed e.g. in [Pu015]; both splitting processes occur for stat and trav fs
interaction of fs: scattering
exp: 2d-dc-GDS – in the course of collision: scattering of two
generation, annihilation of fs: due to interaction
exp: 2d-dc-GDS - fusion in dense arrangements; at fixed parameters: generation of a f by splitting combined with absorption of the new f by a neighbouring one
hexagons in R^2

exp: 2d-dc-GDS – hex pattern

many f systems

exp: 2d-dc-GDS - hex arrangement of fs; liquid-like state of spherical symmetric fs; liquid-like state made of fs with zero-current density intersection line thereby representing an aspherical object with mirrorsymmetry

experimental proof that DS splitting is a generic process in planar dc gas-dischare systems - detection of a new kind of solitary filament and related DS with mirror symmetry

Pu127: Purwins, Amiranashvili (2007)

summary - simple patterns: e.g. isolated solitary filaments and related DSs, stripes, hexagons and rotating spirals - patterns of higher complexity with solitary filaments and related DSs as elementary building blocks: e.g."molecules" and "many body systems" in the form of crystal-, liquid-, gas-like arrangements, chains and nets - universal experimental behaviour for a certain class of systems containing: planar ac and dc gas-discharge systems, electrical networks, semiconductor layer systems, chemical solutions and biological systems - theoretical definition of the corresponding universality class: writing down a 3-component reaction- diffusion system serving as a kind of normal form for the qualitative description of the experimentally observed self-organized patterns - illustration of the formation of solitary filaments and related DSs in planar electrical transport systems on the basis of the 2-component reaction diffusion equation - see also: Electrical Networks: Experiment and Theory, AC Gas-Discharge Systems: Experiment, Gas-Discharge: Theory, Semiconductors: Experiment, Semiconductors: Theory, Reaction-Diffusion Equations

Pu131: Purwins (2007)

summary - stressing that the formation of solitary filaments and related DSs in planar low temperature dc and ac gas-discharge systems is a generic phenomenon - stressing that in many respect DSs behave like particles - illustration of the formation of solitary filaments and related DSs in planar electrical transport systems on the basis of the 2-component reaction diffusion equation - experimentally observed phenomena.: e.g. isolated solitary filament and related DSs, snaking, bifurcation from stationary to travelling solitary filament and related DSs, mutual interaction with scattering, "molecule" formation, generation and annihilation as well as "many body systems" in the form of crystal-, liquid-, gas-like arrangements, domain structures and chains and nets - pointing out that the 3-component reaction-diffusion system seems to present a kind of normal form for the qualitative description of self-organized patterns in the discussed gas-discharge systems - listing of potential applications - see also: AC Gas-Discharge Systems: Experiment, Gas-Discharge: Theory, Reaction-Diffusion Equations