Moiré-Free Collimating Light Guide with Low-Discrepancy Dot Patterns

__T. Idé__, H. Numata, H. Mizuta, and Y. Taira

IBM Tokyo Research Lab.

M. Suzuki, M. Noguchi, and Y. Katsu

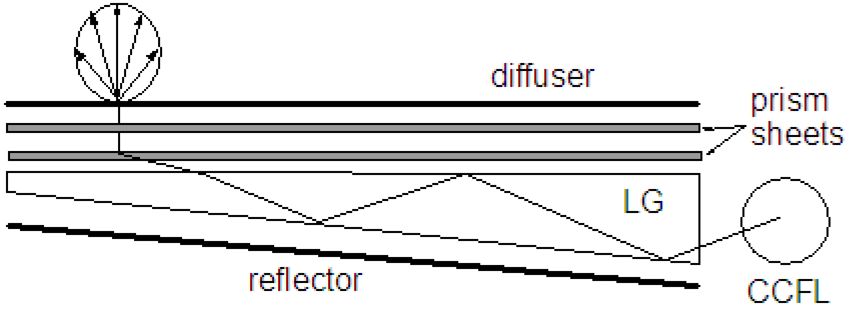
International Display Technology

Agenda

- Background
  - Why must we optimize irregular dot patterns?
- Conventional methods
  - Why is a breakthrough needed?
- Our approach
  - How do we generate the initial pattern?
  - How do we remove inter-dot overlap?
- Implementation
  - How did our approach improve the luminance uniformity?
- Summary

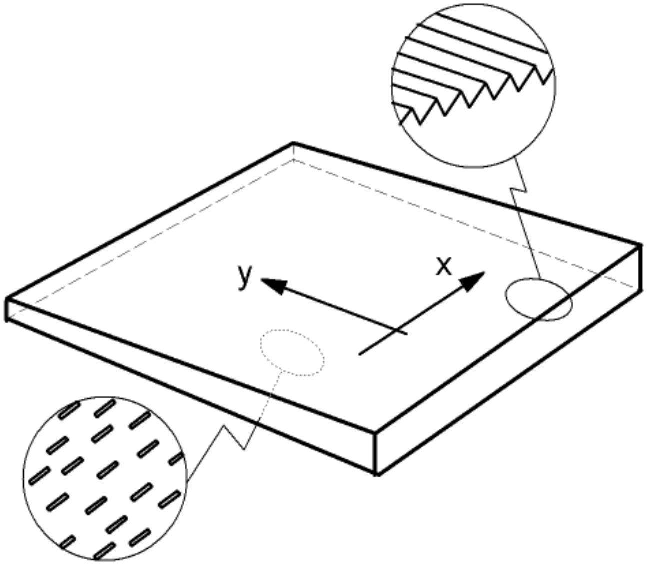
Background

- Edge-lit backlight units
  - Diffusive reflection on the bottom surface of LGs
    - Shape of micro-scatterers
    - Distribution of micro-scatterers
- Need for higher luminance
  - Restriction on physical dimension
  - Restriction on power consumption



A new type light guide

- Integration of a prism sheet
  - Lower loss of flux
- Carefully-designed micro-scatterers
  - In place of conventional diffusing white spots

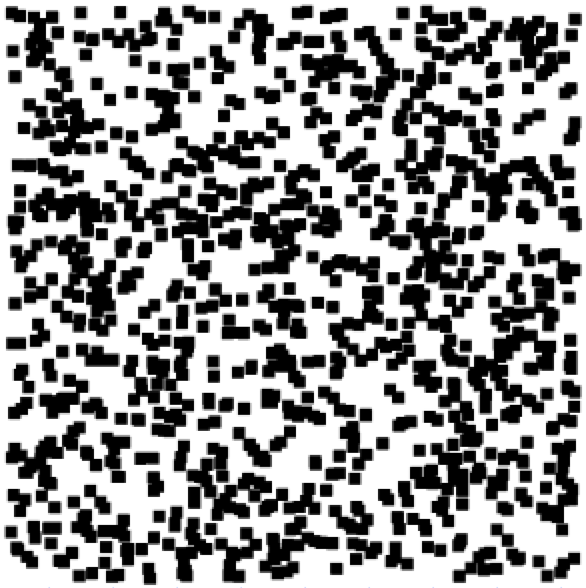


- **transparent**
  - **clear *moiré patterns***
  - **optical interference** : LC cell & micro-scatterers

⇨ *Optimize the distribution of micro-scatterers*

Conventional Methods

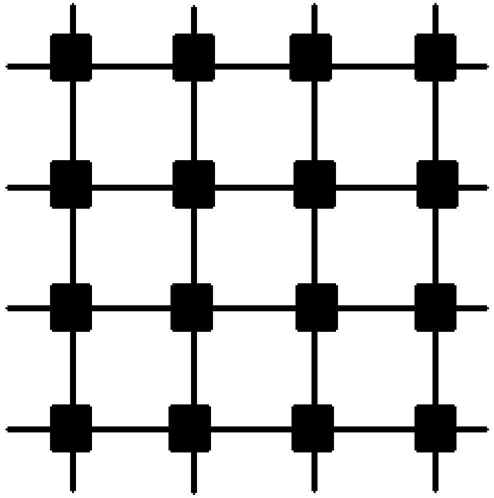
- Simple pseudo-random number method
  - The coordinates are determined directly with pseudo-random numbers
  - Sufficiently irregular
    - No moiré pattern
  - Very rough
    - Visible to the eye
  - Inter-dot overlap
    - Causes anomalous light scattering



“Pseudo-random perturbation” method

- To generate patterns without inter-dot overlap

Regular lattice points

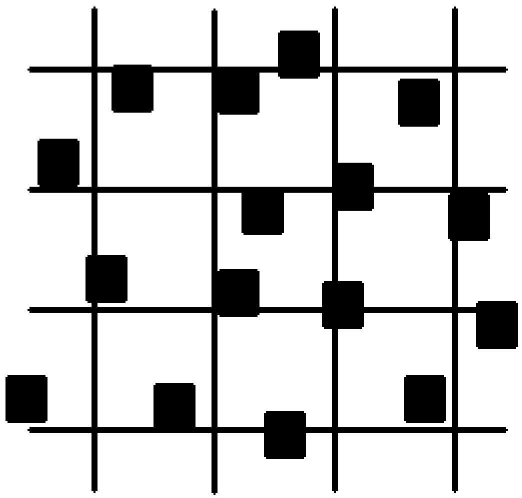


- “Pseudo-random perturbation” method
  - To generate patterns without inter-dot overlap

Regular lattice points

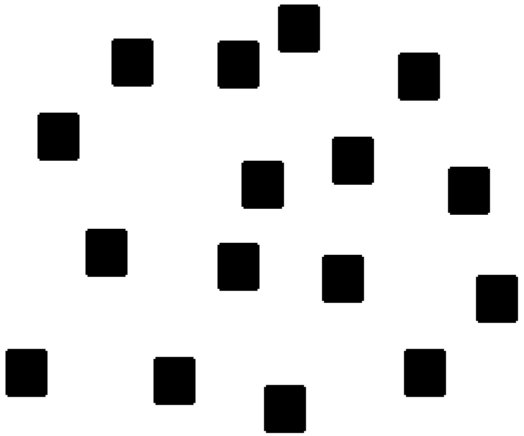
⇩

Random perturbation



“Pseudo-random perturbation” method

- To generate patterns without inter-dot overlap
- Known drawbacks:
  - Visible roughness
  - Difficulties in higher density domains
    - Intractable inter-dot overlap
    - Survival of the periodicity
  - Less flexibility
    - to reproduce density distributions

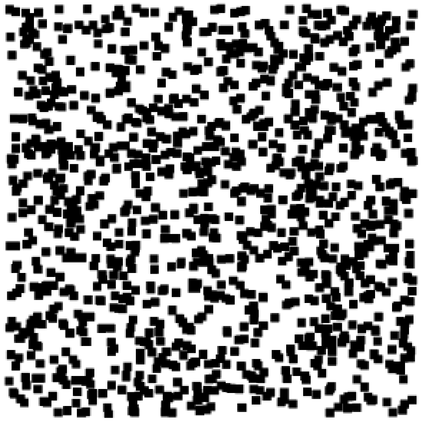


Summary of the conventional methods

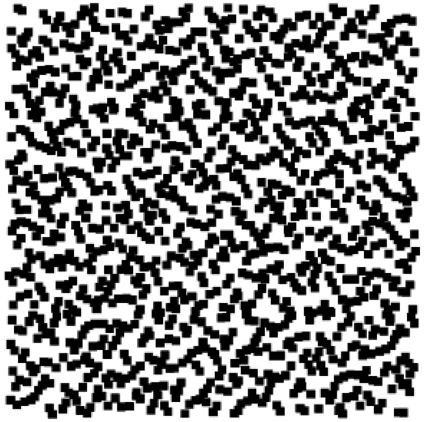
	Moiré prevention	*Uniformity*
Regular array	Extremely bad	Good
Simple pseudo-random	Good	Very bad
Pseudo-random perturbation	Bad	Moderate
Error diffusion methods	Bad	Moderate

Our approach

- Low-discrepancy sequences (LDS)
  - Controlled homogeneity with sufficient irregularity
    - Have been applied for speed-up of Monte Carlo integration/simulations



Pseudo-random



LDS

The first attempt to apply the LDS to physical dot patterns

Need to remove inter-dot overlap…

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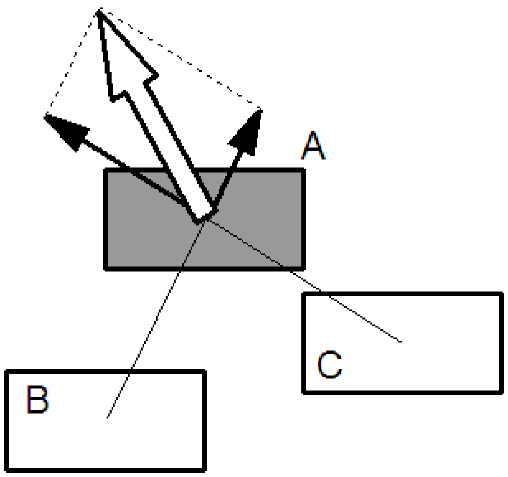
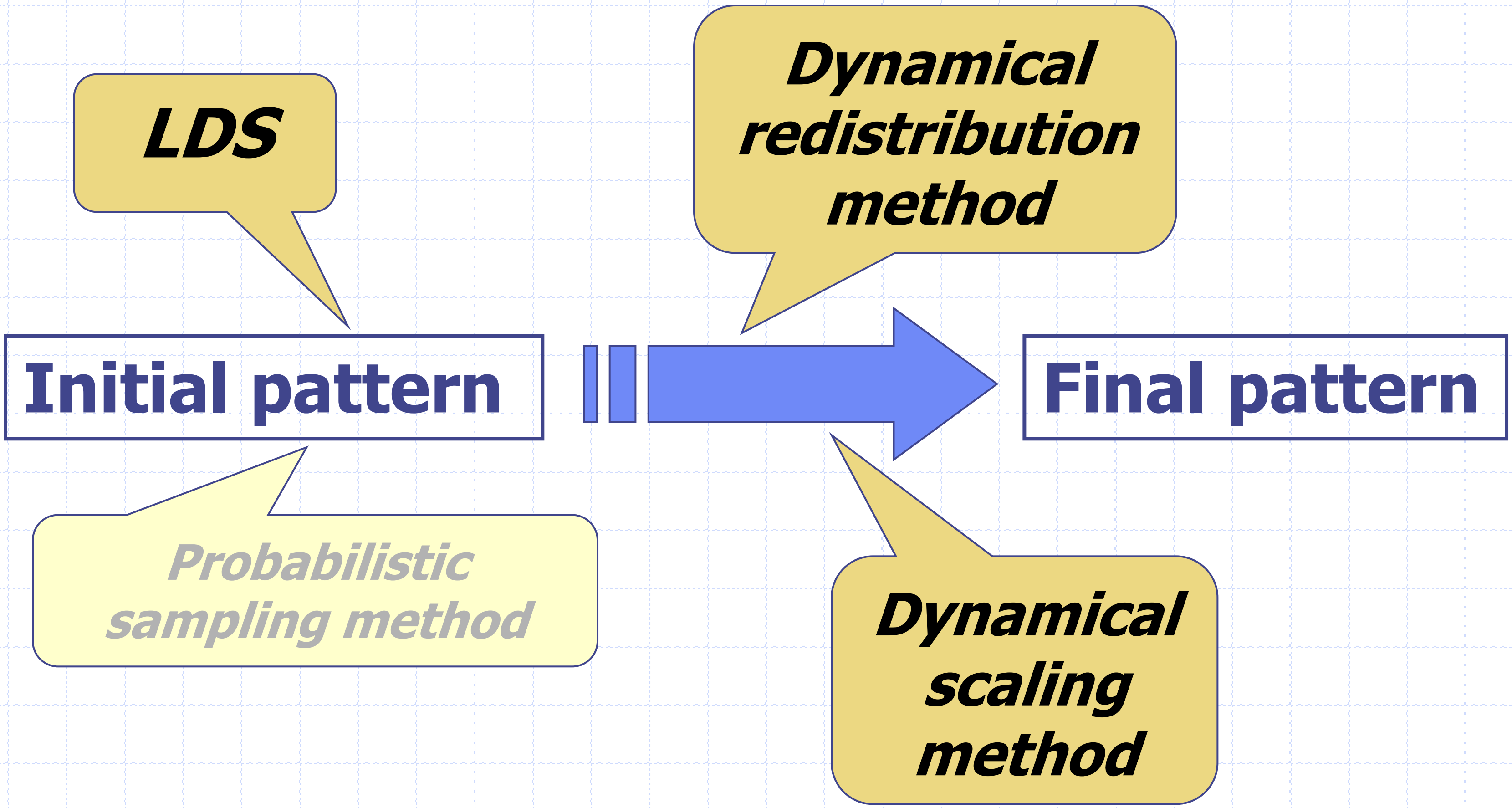


- ## Dynamical redistribution method
  - Give each dot a repulsive force
    - Small distance → strong repulsion
    - Large distance → weak repulsion

The inter-dot overlap is removed gradually as time evolves

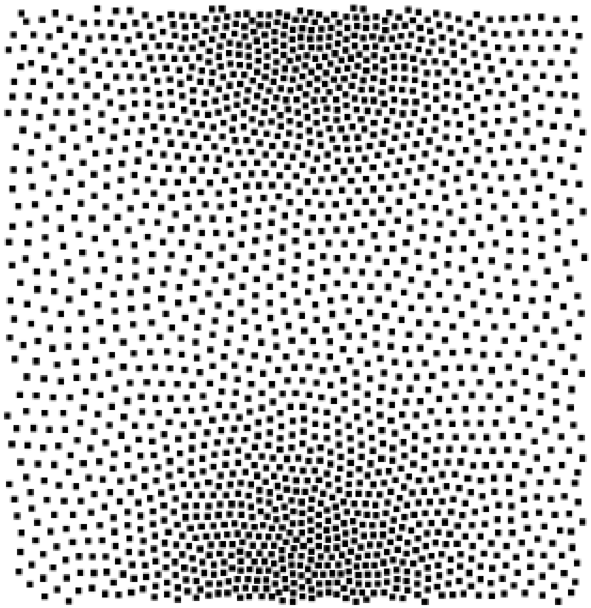
- ## Dynamical scaling method
  - The range of force varies with local density
    - (range) ~ *O* (minimum separation)
    - The principal wavelength (Ulichney 1988)

◆ Summary of our approach

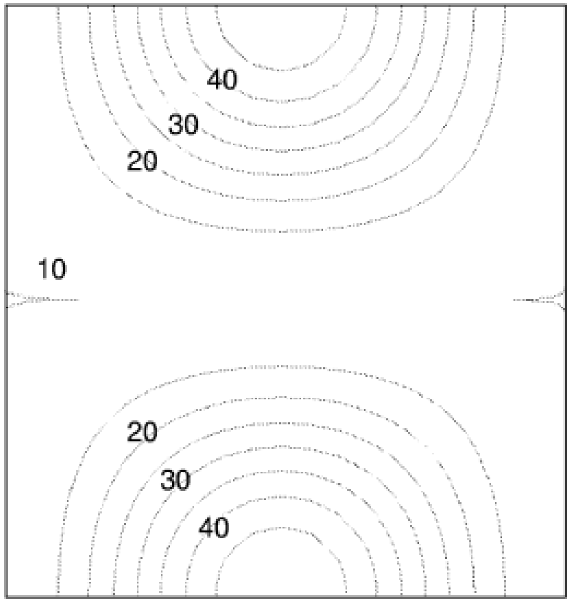


Example 1:

- Steep density gradient is well reproduced
  - From ~10% to ~50%



Generated pattern

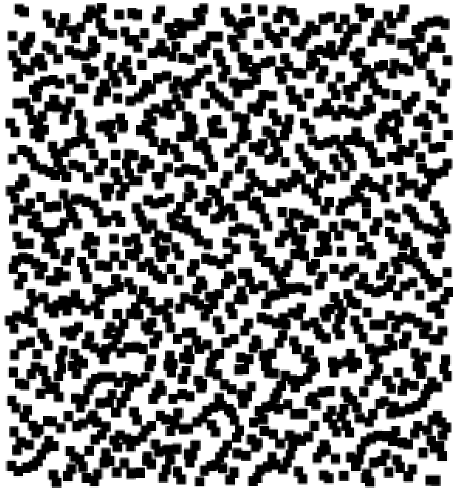


Density distribution

- Example 2:
  - Comparison of two **initial** patterns
    - Pseudo-random and LDS
    - Constant density (~ 60%)

Initial patterns

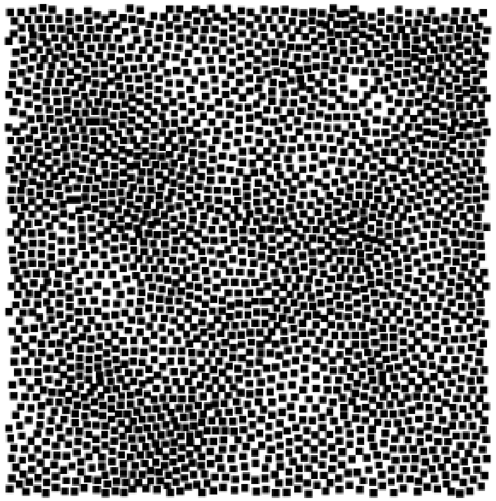
Pseudo-random

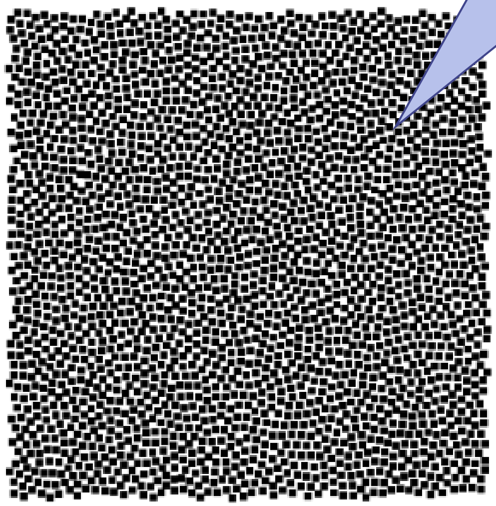


LDS

Example 2:

- Comparison of two **initial** patterns
  - Pseudo-random and LDS
  - Constant density (~ 60%)





random + dynamical

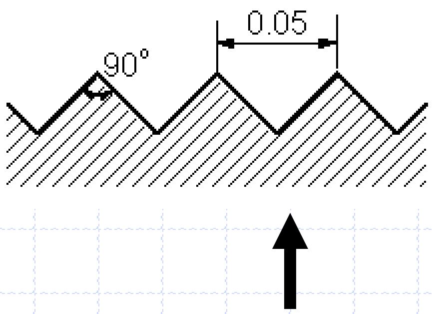
Our method

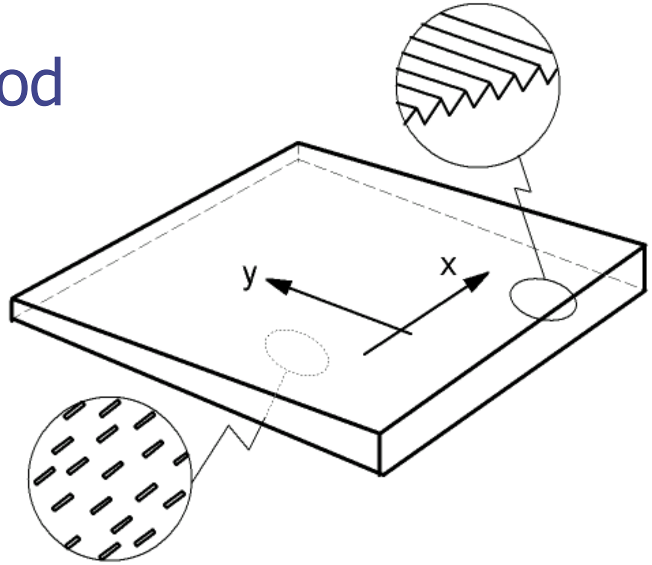
***Final* patterns**

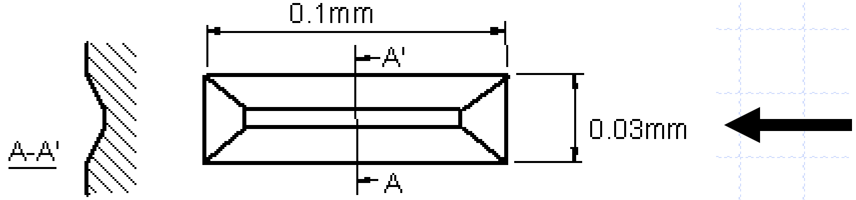
The dynamical redistribution method should be used together with LDS

Implementation

- Integrated-type light-guide
  - 50 μm pitch prismatic grooves
  - 30×100 μm dimples
- Experiment
  - Comparison with the PRP method
  - 15 inch-diagonal UXGA LC cell

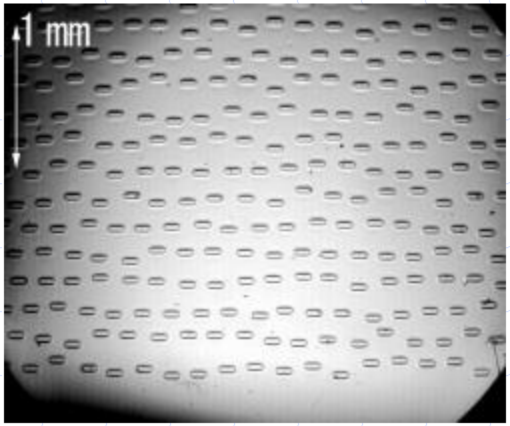






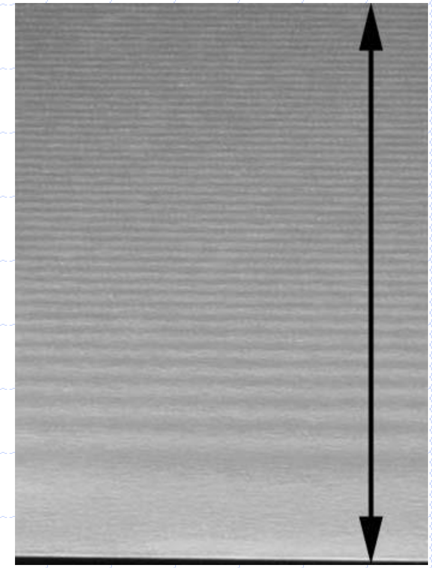
LC cell

A moiré pattern disappears

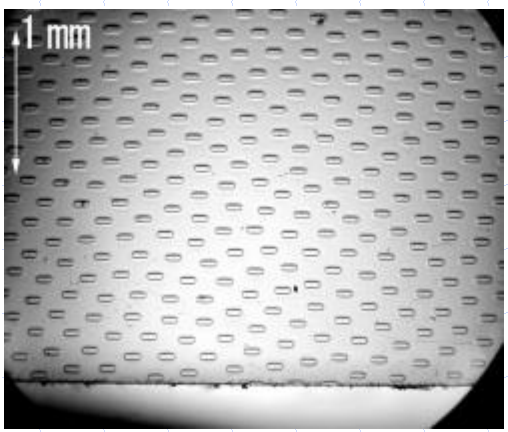


PRP method

(conventional)

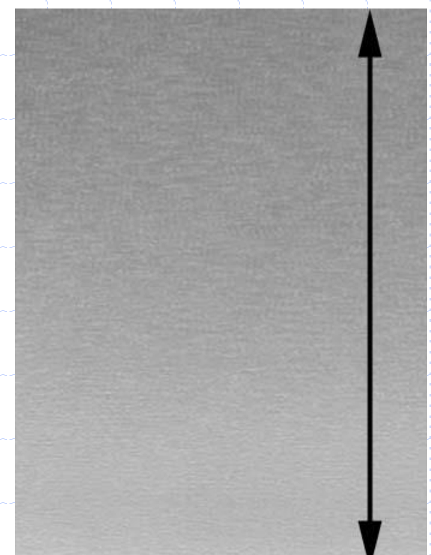


68 mm



Our method

(proposed)



68 mm

Light guide

Summary

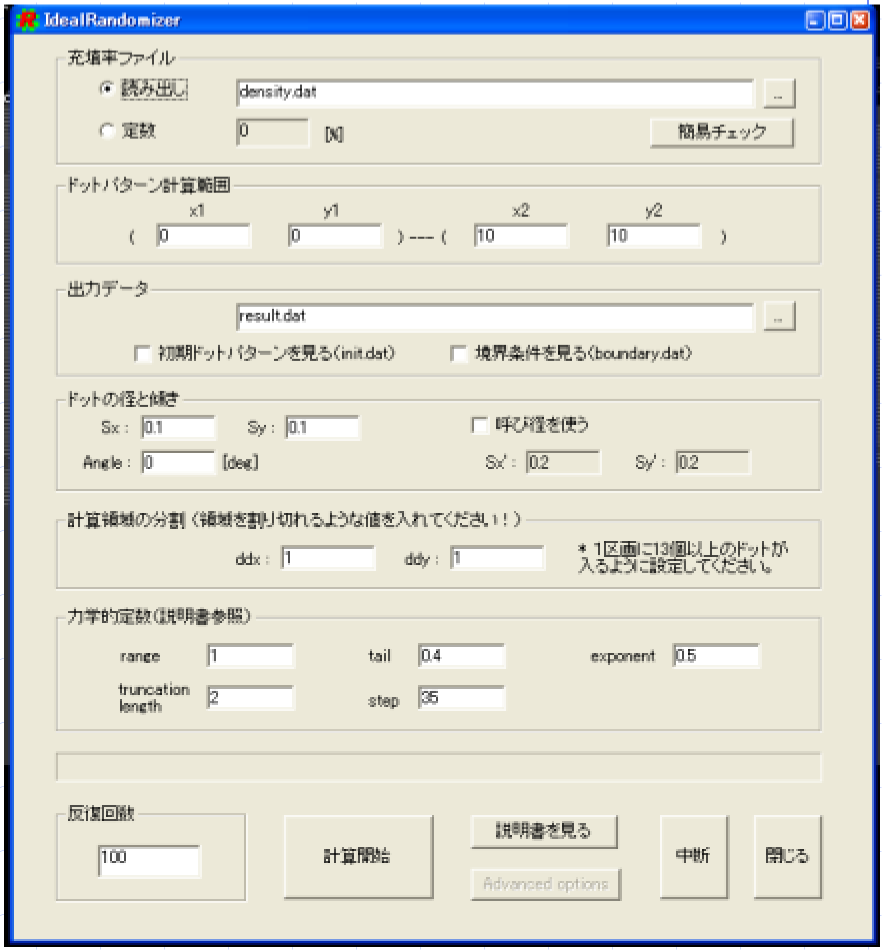
- Integrated-type light guide
  - High luminance
  - Transparent
    - Tends to cause moiré patterns
- Dynamical approach with LDS
  - Super-uniform
  - Sufficiently irregular
  - Flexible: arbitrary density distributions

- Implementation of a moiré-free collimating light guide
  - Achieved high luminance and uniformity
    - Based on our new approach
    - Currently the best randomization method
- IBM ThinkPad A30/A30p
  - First IPS-LCD on laptop PCs
    - "FlexView" display
    - Released in Oct. 2001

Thank you!

Addenda

- IdealRandomizer
  - Simple DLDS pattern generator
    - Any density distributions
    - Outputs text data file



Luminance distribution

- Figure 8