INTEGRATED SOLUTION FOR HOE BASED HOLOGRAPHIC PRINTER

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Holographic Printer Development Goal

- Compact printer size, convenient for consumer electronics by using WGH
- Printing speed increasing
- Low power consumption
- User convenient printing process

3D Holographic Printer

- Conventional Holo Printer
- CE Holo Printer

Printer Size reduction
- Integrate conventional optical elements by WGH and replace conventional optical elements

Printing speed-up
- Multi-focale/Head array optical architecture
- Low vibration sensitivity of the system
- High sensitive Holographic Material

Low Power consumption
- Increase total efficiency of the optical system
- Use LD as coherent light source

User convenient printer process
- Film type printing material
- Dry and fast post processing

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Principle of Holographic 3D Printer

Recording

Reference beam

Interference pattern

Hologram exposure

Polymerization

Reconstruction

Reconstructed light

Signal beam wave fronts (equidistant phase surfaces)

Signal beam wave fronts (equidistant phase surfaces)

Intensity profile correlated to the interference between signal and reference beams

Photopolymer working mechanism

Linear irradiation

Photo initiation

Initiation line

Hologram formation

Signal beam

Fresnel Lens

SLM

Kerr Lens

Hologram exposure

Polymerization
Minimization of Optical Head with WGH

- Size reduction: 10 times reduction of optical system using waveguide hologram
- Efficiency improvement by utilizing HOE (theoretically -100%)

Conventional Element: Volume ~350cm³

Waveguide Hologram: Volume ~21.6cm³

Replace 6 conventional optical elements by 2 HOEs
- Beam Splitter, Lens (Beam Expansion) → HOE1 (Input)
- Lens, Mirror, Flat-Top Filter → HOE2 (Output)

[Radius of Grating for Lens]
\[ r = \sqrt{n_2 v_f + \frac{n_1^2 \lambda^2}{4}} \]

[Efficiency for HOE]
\[ \eta = \tan^2 \left( \frac{\pi n_2 v_f}{2} \right) \]

High optical efficiency by WGH
- Glass Transmitance (~0.999)
- TIR Reflectance (~0.999)
- DE of HOE1 (~1.44)

Geometrically slim form factor benefit by using WGH
- Folding the optical path within waveguide

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Waveguide Hologram Unit Development

Recording scheme of H1 & H2 hologram (record H1 first, then H2)

A

B
Integrate Full Color Head

Development of the compact optical printing head for full color printer

- Full color optical head requires special color cross-talk minimization system

For side by side type color system
- Optical system is complicated
- Need 3 SLM, 3 objective lens
- Printing time increase by 3 times (vs. mono color)
- No cross-talk

For stacked color system
- Simple optical system (same as mono-color)
- Printing time is the same as mono-color
- Cross-talk might be an issue

Cross-talk for stacked color system

Define cross-talk for different wavelengths
RGB Cross-talk Minimization for WGH

Parameterization / Assumptions

Critical Design Parameters:
- Material thickness, \( d \)
- Refraction index modulation, \( \Delta n \)
- Material absorption
- Tolerance

Mathematical Formulation

Maximization Parameters: Efficiencies

Maximization Parameters: Genome of RGB Cross-talks

Fixed Condition Parameters

Min-Max problem is

For film type (thickness fixed), it reduces to:

\[ \max_{\text{Max}} \left( \sum_{i=1}^{3} f(\Delta n_i) \right) \]
Full Integrated Printer Head

Reference Arm Recording scheme

- Recorded hologram illuminated by reconstruction beam
- Direct hologram view
- Forward hologram spot

Integrated Head

- The fully integrated optical printing head
  - WGH based beam splitting
  - WGH with integrated Phase Mask to make Flat-top beam transformation and holographic shaping
  - HOE based reference beam forming unit
  - Solid design to provide low vibration sensitivity
  - LD as coherent light source

Object Beam Forming Unit (OBFU) Illuminator

Sensitivity material plane

Reference Beam Forming Unit

TIR Prism

Laser
Printed Hologram Results

- All Samples were printed with recorded RGB WGH units
- The RGB hogels were recorded simultaneously for all colors
- The samples were directly recorded on Bayer Photopolymer material