
On-chip space–time wave packet laser array

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1. Analysis of the incoherent space-time wave packets

Below, we provide a rigorous derivation demonstrating that the synthesized incoherent space-time (ST) field preserves its transverse intensity profile during propagation.

$$G(x_1, z, t_1; x_2, z, t_2) = \langle E(x_1, z, t_1) E^*(x_2, z, t_2) \rangle$$

where $\langle \cdot \rangle$ denotes an ensemble average. In Fourier space, this correlation function of the synthesized ST wave (after formation at $z = 0$) can be written as follows

$$\begin{aligned} G &= \iint dk_x dk'_x \iint d\omega d\omega' \langle \tilde{E}(k_x, \omega) \tilde{E}^*(k'_x, \omega') \rangle e^{i(k_x x_1 - k'_x x_2)} e^{i(k_z - k'_z)z} e^{-i(\omega t_1 - \omega' t_2)} \\ &= \iint dk_x dk'_x \iint d\omega d\omega' \tilde{G}(k_x, \omega; k'_x, \omega') e^{i(k_x x_1 - k'_x x_2)} e^{i(k_z - k'_z)z} e^{-i(\omega t_1 - \omega' t_2)} \end{aligned} \quad (S1)$$

where $\tilde{G}(k_x, \omega; k'_x, \omega') = \langle \tilde{E}(k_x, \omega) \tilde{E}^*(k'_x, \omega') \rangle$ represents the correlation function in the spatial and temporal frequency domain. As discussed in the main manuscript, for incoherent space-time wave packets (STWPs), k_x and ω are related according to

$$k_x = \pm \sqrt{\frac{2k_0(\omega - \omega_0)(1 - \tan \theta)}{c}} \quad (S2)$$

Accordingly, the Fourier transform of the electric field can be written as $\tilde{E}(k_x, \omega) = \tilde{E}(k_x) \delta(\omega - f(k_x))$ and hence $\tilde{G}(k_x, \omega; k'_x, \omega') = \tilde{G}(k_x; k'_x) \delta(\omega - f(k_x)) \delta(\omega' - f(k'_x))$. Substituting this form into Eq. (S1) reduces the correlation function to

$$G = \iint dk_x dk'_x \tilde{G}(k_x; k'_x) e^{i(k_x x_1 - k'_x x_2)} e^{i(k_z - k'_z)z} e^{-i[f(k_x)t_1 - f(k'_x)t_2]} \quad (S3)$$

For the STWPs considered here, spectral amplitudes associated with different spatial frequencies are mutually incoherent except for the paired components $\pm k_x$, which are emitted by the same laser and thus remain mutually correlated. The central lobe in the time-averaged intensity originates from this mutual coherence, as each correlated $\pm k_x$ pair contributes a spatially localized interference feature. Accordingly, for each pair of beams corresponding to the same wavelength, $\tilde{G}(k_x; k'_x)$ takes the form $\tilde{G}(k_x) \delta(|k_x| - |k'_x|)$, which can be rewritten as

$$\tilde{G}(k_x; k'_x) = \tilde{G}_1(k_x) \delta(k_x - k'_x) + \tilde{G}_2(k_x) \delta(k_x + k'_x)$$

Here, $\tilde{G}_1(k_x) = \tilde{G}(k_x, k_x)$ denotes the self-correlation term, whereas $\tilde{G}_2(k_x) = \tilde{G}(k_x, -k_x)$ denotes the mutual correlation between the paired $\pm k_x$ components. Equation (S3) then reduces to a single integral over k_x . Since the correlated terms satisfy $k'_x = |k_x|$, the dispersion relation yields $k_z = k'_z$, and the propagation-dependent phase factor $e^{i(k_z - k'_z)z}$ reduces to unity. As a result, Eq. (S3) becomes independent of z , and can be rewritten as

$$G = \int dk_x [\tilde{G}_1(k_x) e^{ik_x(x_1 - x_2)} + \tilde{G}_2(-k_x) e^{-ik_x(x_1 + x_2)}] e^{-i\omega(t_1 - t_2)} \quad (S4)$$

Hence,

$$G = G_1(x_1 - x_2, t_1 - t_2) + G_2(x_1 + x_2, t_1 - t_2)$$

where $G_j(x, t) = \int dk_x \tilde{G}_j(k_x) e^{i(k_x x - \omega t)}$, $j = 1, 2$. The time-averaged intensity is then obtained from

$$I(x) = G(x, z, t; x, z, t) = G_1(x = 0, \tau = 0) + G_2(2x, \tau = 0) \quad (S5)$$

where $\tau = t_1 - t_2$. From Eq. (S4) one can readily deduce that $G_1(x = 0, \tau = 0)$ is a real constant. Given that six plane-wave-like components synthesize the STWP, we can infer that $G_2(2x, \tau = 0) = \sum_n |E_n|^2 (e^{-2ik_{xn}x} + e^{2ik_{xn}x})$ while $G_1(x = 0, \tau = 0) = \sum_n 2|E_n|^2$ where E_n is the amplitude of the emitted field from the n -th pair. From here, one can conclude that indeed the intensity of the STWP remains invariant while exhibiting a dominant central lobe in its intensity profile. For instance, with a central wavelength λ_0 of 1550 nm, a spectral bandwidth of 10 nm, and $\theta = 30^\circ$, the resulting spatiotemporal correlation calculated from Eq. (S2) is shown in Fig. S1a. Here, each ω is mapped one-to-one onto $|k_x|$, so that each frequency component in the calculation is composed of two plane waves with transverse wave vectors $\pm k_x$. The time-averaged intensity profile constructed from these spectral components is shown in Fig. S1b, where a central peak is clearly observed. Since Eq. (S5) is independent of z , the central peak of the synthesized ST field remains invariant during propagation.

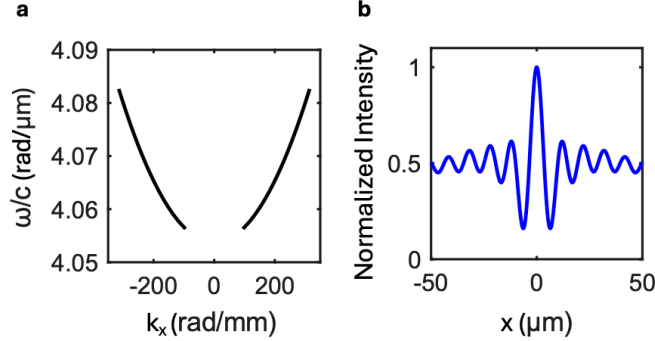


Fig. S1. Numerical calculation of the intensity profile. (a) Correlation between spatial and temporal frequencies. (b) Normalized intensity derived from the correlation function.

2. Design of the distributed feedback laser arrays

In this work, a symmetric laser array for generating incoherent ST fields was fabricated on an indium phosphide (InP) substrate incorporating indium gallium arsenide phosphide (InGaAsP) multiple quantum wells (QWs). The array comprises six distributed feedback (DFB) lasers, each integrated into a waveguide with width $w_{wg} = 1.8 \mu\text{m}$ and total height $h = 700 \text{ nm}$, consisting of an $h_{\text{InP}} = 200 \text{ nm}$ InP layer and an $h_{\text{QW}} = 500 \text{ nm}$ QW region. A three-dimensional COMSOL grating simulation reveals two photonic band edges corresponding to the stopband (Fig. S2a). From the extracted stopband width Δf , the coupling coefficient is determined as $\kappa = n_{\text{eff}}\pi\Delta f/c = 17000 \text{ m}^{-1}$, where n_{eff} is the effective refractive index of the waveguide. The DFB cavity length is set to $L_{\text{DFB}} = 200 \mu\text{m}$ to achieve $\kappa L_{\text{DFB}} = 3.4$.

Using the extracted coupling coefficient, we subsequently solve the coupled wave equations governing the forward and backward propagating waves within the DFB cavity:

$$\begin{bmatrix} A(z+L) \\ B(z+L) \end{bmatrix} = \begin{bmatrix} e^{-i\delta L} & e^{i\kappa L} \\ e^{-i\kappa L} & e^{i\delta L} \end{bmatrix} \begin{bmatrix} A(z) \\ B(z) \end{bmatrix} \quad (\text{S6})$$

where $\delta = \beta - \beta_{\text{Bragg}}$ denotes the detuning from the Bragg condition. To determine the spectral response, we impose the boundary conditions at the output facet as $A(L_{\text{DFB}}) = 1$ and $B(L_{\text{DFB}}) = 0$, solve the equations backward to $z = 0$, and normalize the fields such that $A(0) = 1$ corresponds to unit excitation from the input. The resulting reflection spectrum,

$$R = 1 - T = 1 - \frac{|A(L_{\text{DFB}})|^2}{|A(0)|^2} \quad (\text{S7})$$

is plotted in Fig. S2b.

A central phase-shift section is inserted in the DFB structure to support single-mode operation. The spectral spacing between the laser elements is designed to be 0.7 nm so that they experience similar optical gain. The length of the phase-shift section is systematically varied to precisely tune the lasing wavelength

according to the spectral-position correspondence (Eq. 1 in the main text)¹. Figure S2c illustrates the resulting shift in the stopband as a function of the phase-shift length. A 17.57 nm increase in the phase-shift length yields a 1.0 nm shift in the emission wavelength, thereby easing lithographic resolution constraints. The array is designed to emit around a central wavelength of $\lambda_0 = 1587$ nm with a total spectral bandwidth of 3.6 nm.

The spatial arrangement of the DFB lasers follows a predefined mapping (Eq. 1 of the main text), implemented via a bus waveguide structure that connects each cavity to its designated position. In accordance with this mapping, achieving a narrower beam width requires larger separations between emitters. Additionally, the waveguide design ensures a minimum bending radius of 100 μm and a uniform optical path length of 1.51 mm across all elements, thereby maintaining equal optical output power.

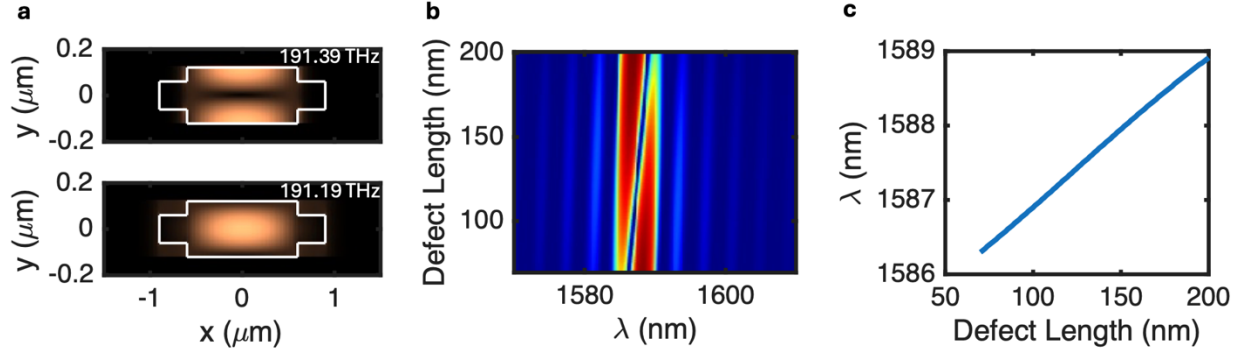


Fig. S2. Design of the DFB laser arrays. (a) Band-edge modal profile of the grating unit cell computed using periodic boundary conditions along the propagation axis to represent an infinite grating structure. (b) Calculated reflectance spectrum of the DFB grating structure. (c) Dependence of the operating wavelength on the introduced defect length.

3. Effect of discrete spectral sampling

In the present architecture, the ideal continuous spatiotemporal spectrum is approximated by a finite number of discrete emitters, and this discretization can produce side lobes that reduce the purity of the synthesized field. Even so, the experimental configuration with only six emitters already captures the essential behavior of the continuous case with good fidelity. As shown in Fig. S3a, the side lobe suppression ratio (SLSR), defined as the ratio of the central-peak intensity to the peak side lobe intensity, grows from 1.00 to 1.65 as the number of emitters is increased from 1 to 50, whereas the six-emitter case already attains a value of 1.52. This trend is also evident in the corresponding transverse intensity profiles shown in Fig. S3b.

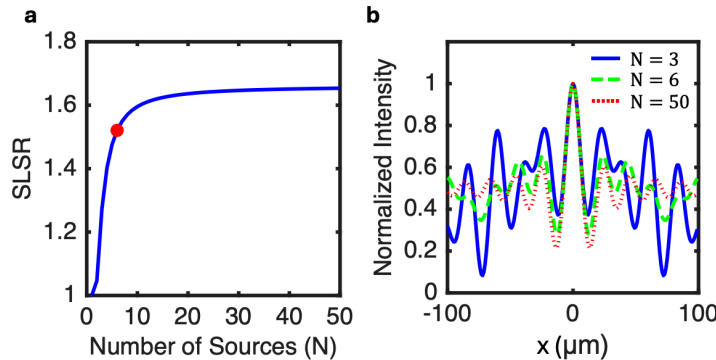


Fig. S3. Effect of discrete spectral sampling. (a) SLSR with respect to the number of emitters. (b) Simulated normalized transverse intensity profiles comprising 3, 6, and 50 emitters.

4. Spatial demagnification of the ST field

The transverse width of the central lobe of an ST field is primarily determined by the spectral tilt angle θ of the spectral plane and by the available spectral bandwidth. Decreasing θ narrows the central lobe but also reduces the fraction of optical power concentrated within it (Fig. S4a). In practice, a further reduction in beam size may nevertheless be desirable for applications requiring tighter spatial confinement. Here, we employ external optical demagnification to obtain a smaller lobe while preserving the relative spatial distribution of the field, and thus its energy efficiency.

In our experiments shown in Fig. S4b, the ST field emitted from the chip is first demagnified using a $4f$ imaging system with a total magnification factor of $0.1\times$. Owing to this geometric scaling, the central lobe width decreases in proportion to the magnification factor M , while the propagation-invariant distance scales as M^2 . To clearly resolve the ST patterns with a near-infrared (NIR) camera, the field is subsequently magnified with a microscope objective ($11.58\times$) and projected onto the sensor. To quantify the effect of demagnification, we measured the transverse intensity distribution before and after the $4f$ relay system, obtaining full width at half maximum (FWHM) values of $61\text{ }\mu\text{m}$ and $6.1\text{ }\mu\text{m}$, respectively. In both cases, the spatial confinement of the central lobe is preserved, as expected.

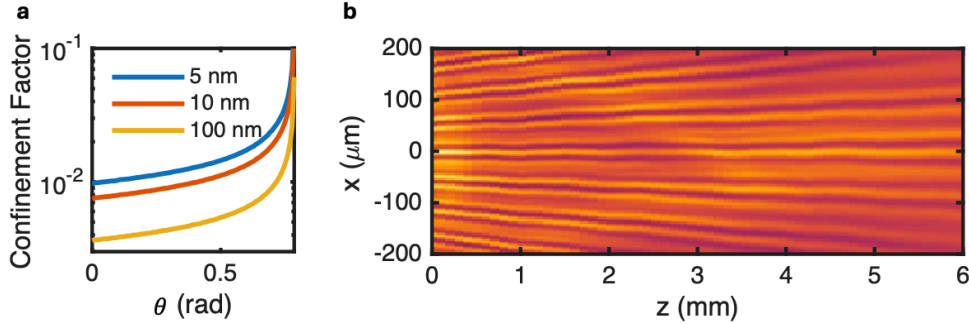


Fig. S4. Spatial demagnification of the ST field. (a) Simulated confinement factor of the central lobe for three spectral bandwidths and spectral tilt angles ranging from $\theta = 0$ to $\pi/4$. The confinement factor is defined as the fraction of the total power contained in the central lobe. (b) Measured time-averaged intensity profile of a demagnified ST field with a demagnification factor of $0.1\times$, corresponding to $\theta = 44.7^\circ$.

5. Robustness of STWP generation against spectral distortion

In this section, we examine the robustness of the synthesized ST field against two practical spectral imperfections: finite laser linewidth and wavelength detuning.

In the ideal case, each emitter contributes to a single wavelength lying on the designated $k_x - \omega$ trajectory. A finite linewidth replaces this discrete assignment with a narrow spectral distribution for each channel, thereby softening the mapping and increasing spectral overlap between neighboring emitters. To evaluate this effect, we carried out simulations assuming Lorentzian linewidth profiles with FWHM values of 0.01, 0.1, and 0.5 nm. It should be noted that for DFB lasers a linewidth of 0.1 nm is already much larger than what can be reasonably achieved. Although the broadened spectra in Figs. S5a, S5c, and S5e partially wash out the discrete sampling of the target correlation, the corresponding time-averaged intensity profiles in Figs. S5b, S5d, and S5f remain to a great extent preserved. These results indicate that the propagation-invariant behavior is highly robust to finite laser linewidth.

The second type of imperfection arises when the lasing wavelengths of the individual spectral channels deviate from their intended values, mainly induced by fabrication errors and temperature variations. Such deviations introduce relative detuning across the array and perturb the designed spatiotemporal correlation. To test the sensitivity of the ST field to this distortion, we randomly offset the wavelength by 2%, 5%, and 10% of the total bandwidth (Figs. S6a, S6c, and S6e). The resulting propagation dynamics, shown in Figs. S6b, S6d, and S6f, remain essentially unchanged. We therefore conclude that moderate perturbations of the spectral structure do not significantly affect the formation of the ST field.

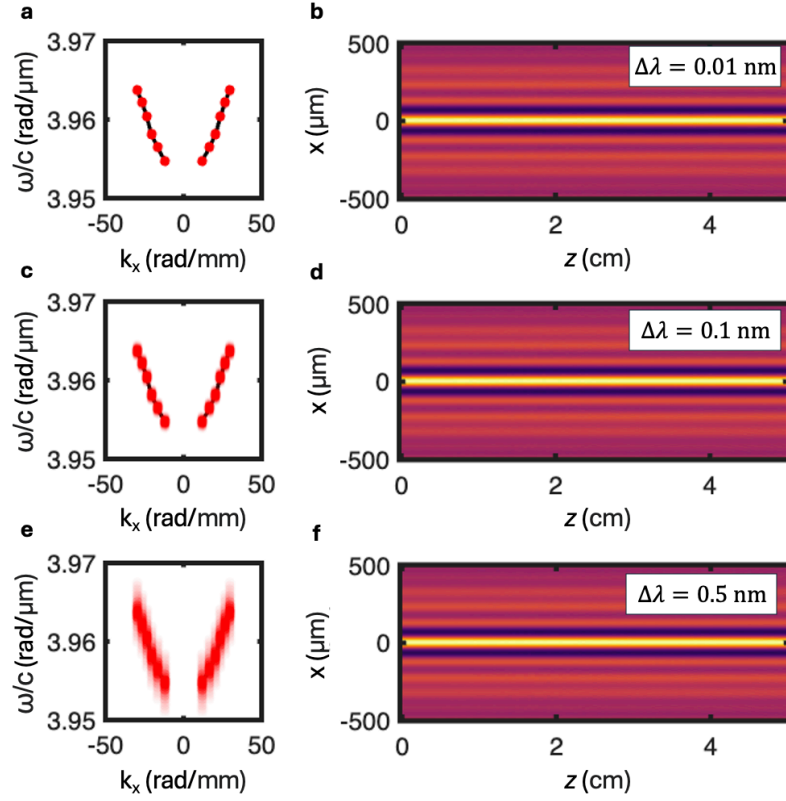


Fig. S5. Stability of the ST field under linewidth broadening. (a, c, e) Spatiotemporal correlations calculated assuming Lorentzian linewidth profiles of 0.01 nm, 0.1 nm, and 0.5 nm, respectively. The solid curve shows the ideal parabolic correlation, and the red markers indicate the discrete sampled spectrum. (b, d, f) Corresponding simulated time-averaged intensity profiles.

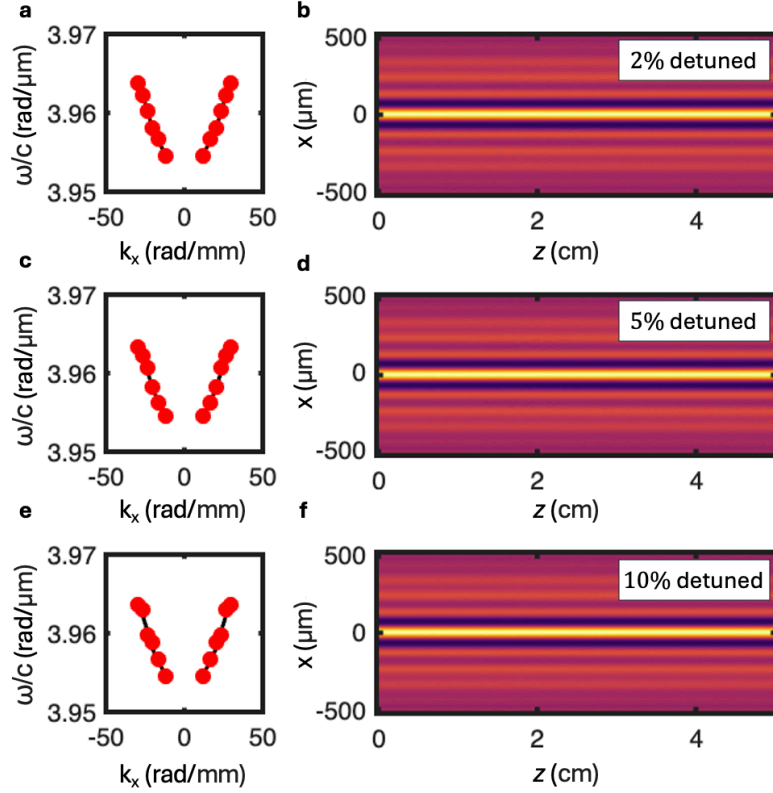


Fig. S6. Stability of the ST field under perturbations. (a, c, e) Spatiotemporal correlations with random detuning of 2%, 5%, and 10% in the temporal frequency. The solid curve shows the ideal parabolic correlation and the red markers indicate the detuned discrete spectrum. (b, d, f) Simulated time-averaged intensity profile under detuned conditions.

6. Additional characterization of self-healing ST field

In this section, we provide additional experimental observations of self-healing for different values of θ . Figures S7b and S7f present self-healing measurements for arrays with $\theta = 41.0^\circ$ and $\theta = 46.0^\circ$, respectively, complementing the result in Fig. 4c and Fig. S7d for $\theta = 44.7^\circ$. The corresponding simulations, shown in Figs. S7a, S7c, and S7e, are in good agreement with the experimental results. The wire used in all experiments had a diameter of $80\ \mu\text{m}$, corresponding to approximately $4.8\times$, $1.3\times$, and $2.6\times$ the central lobe widths of the ST field for $\theta = 41.0^\circ$, $\theta = 44.7^\circ$, and $\theta = 46.0^\circ$, respectively.

In the present geometry, the strength of self-healing is governed by two characteristic scales: the widths of the ST field central lobe and the Gaussian envelope emitted from each individual laser at the back focal plane of the Fourier lens. Specifically, a narrower central lobe corresponds to larger transverse spatial frequencies, causing the unblocked portions of the field to converge and interfere more rapidly after the obstacle, and thus leading to a shorter healing distance. By contrast, the Gaussian envelope determines the fraction of the field that remains unblocked, and therefore sets the upper bound on the obstacle size for which self-healing can still occur. For a fixed central lobe width, self-healing remains effective as long as the obstacle is appreciably smaller than the Gaussian envelope (experimentally $80\times$ the central lobe width), so that a sufficient portion of the field survives after obstruction and can subsequently recombine constructively on axis.

We also examined the effect of obstruction size through additional simulations with obstacle diameters of $150\ \mu\text{m}$, $750\ \mu\text{m}$, and $1500\ \mu\text{m}$ (Fig. S8). These values were selected to span a broad range of perturbation strengths, with the largest diameter chosen to be comparable to the Gaussian envelope of the field at the back focal plane of the Fourier lens. The transverse profiles in Figs. S8c, S8f, and S8i show that the central

lobe is restored in all cases, with the restoration shifting to further axial distances as the obstruction increases. These results provide a quantitative assessment of the obstruction over which self-healing remains effective.

The recovery distance is determined by θ through the underlying spatiotemporal correlation. A smaller θ corresponds to a steeper $\omega_n - k_{xn}$ relation and thus to larger accessible transverse spatial frequencies for a fixed temporal bandwidth. These larger k_x components direct stronger transverse energy flow into the obstructed region, allowing the central lobe to reconstruct more rapidly. Consequently, the self-healing distance decreases with smaller θ , consistent with both the simulations and the experimental observations.

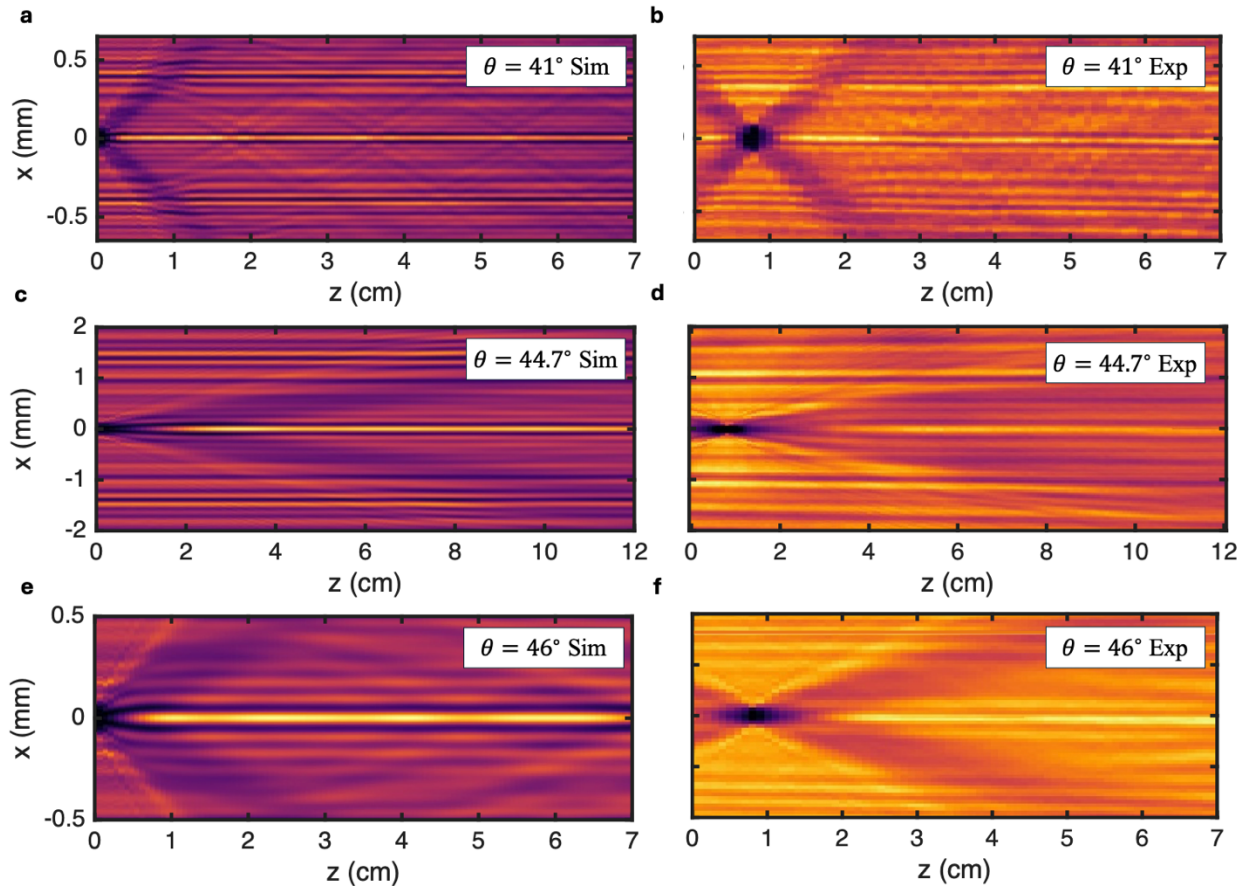


Fig. S7. Characterization of the self-healing ST field. (a, c, e) Simulated propagation of the self-healing ST field for $\theta = 41^\circ$, 44.7° , and 46° , respectively. An $80\ \mu\text{m}$ diameter obstruction is placed at the beam center. (b, d, f) Characterization of the corresponding self-healing ST fields for $\theta = 41^\circ$, 44.7° , and 46° , respectively.

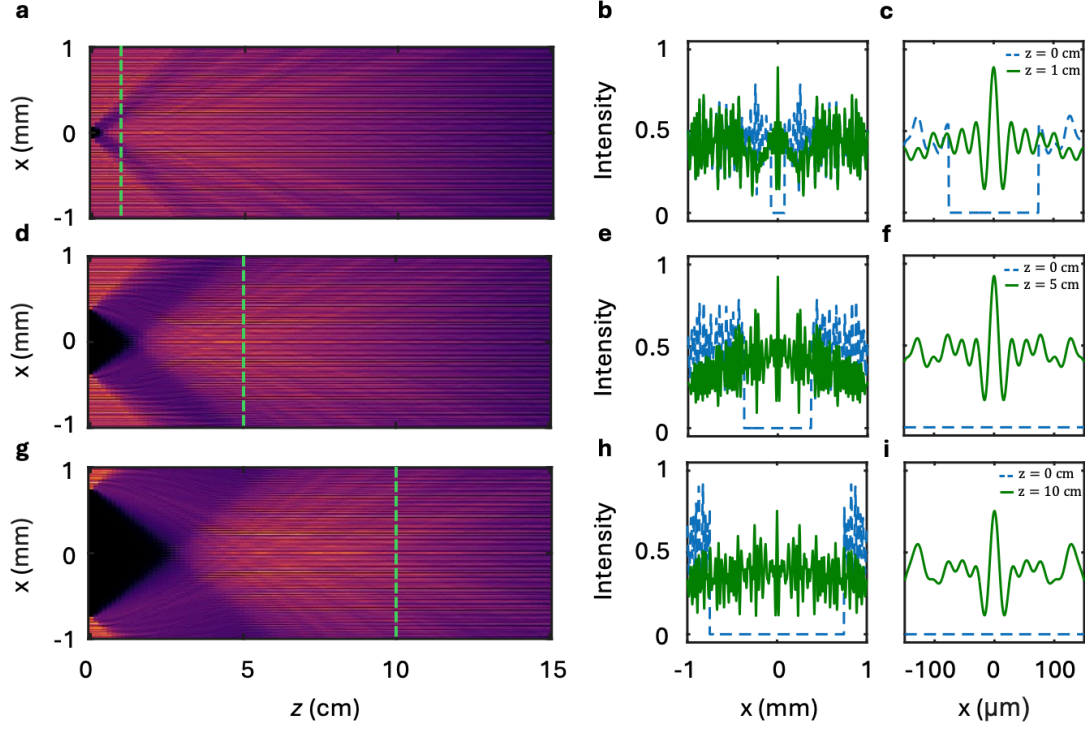


Fig. S8. Simulation of the self-healing ST field after obstruction. (a, d, g) Time-averaged intensity distributions of the obstructed ST field for wires with diameters of 150 μm , 750 μm , and 1500 μm , respectively. (b, e, h) Corresponding transverse intensity profiles. The blue curve indicates the profile measured at the obstruction plane ($z = 0$ cm), while the green curve shows the profile after propagation to $z = 1$ cm, 5 cm, and 10 cm in panels b, e, and h, respectively. (c, f, i) Magnified views of the central lobe from (b, e, h).

7. General applicability of the on-chip STWP generation scheme

In this section, we discuss the general applicability of the proposed STWP generation scheme with respect to the central wavelength λ_0 . The essential requirement for STWP formation is the engineered correspondence between emitter wavelength and transverse position, which gives rise to the desired spatiotemporal correlation. Varying λ_0 , however, primarily rescales the spatial dimensions of the generated field rather than altering the underlying mechanism, and thus preserves the STWP synthesis process.

To verify this behavior, we performed comparative simulations in which λ_0 was varied over a broad range while the emitter positions were rearranged accordingly at a fixed θ . Figures S9a-c show the simulated intensity distributions for representative central wavelengths of 400 nm, 800 nm, and 2 μm , respectively, while Fig. S9d summarizes the corresponding FWHM as a function of λ_0 . In all cases, STWPs are successfully synthesized, with the central lobe becoming broader at longer wavelengths.

These results indicate that extending the design to other spectral bands is promising. Among possible implementations, III-V semiconductor laser arrays provide the most direct and practical route because they combine on-chip gain with broad spectral coverage extending from the ultraviolet to the NIR. The same concept may also be extended to longer wavelengths using quantum cascade heterostructures in the mid-infrared and terahertz regimes. Alternative approaches based on multimode lasers or on-chip frequency-comb sources may also be available.

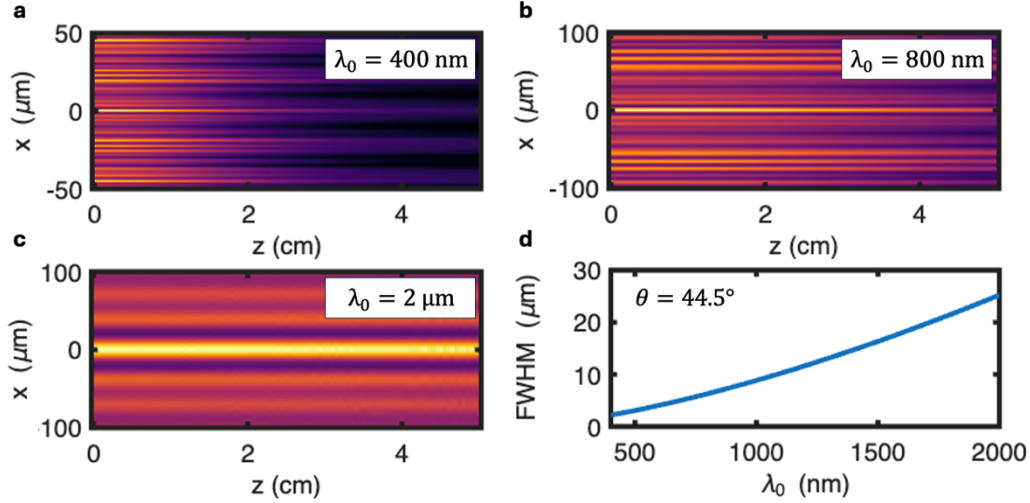


Fig. S9. Influence of the central wavelength λ_0 . (a, b, c) Simulated time-averaged axial intensity distributions for central wavelengths $\lambda_0 = 400$ nm, 800 nm, and 2000 nm, respectively. (d) Simulated FWHM as a function of λ_0 at a spectral tilt angle θ of 44.5° .

8. Applications

The present platform combines several attributes that are directly relevant to imaging modalities requiring an extended depth of focus: a narrow beam width potentially reaching the sub-micrometer scale, a propagation-invariant distance that is orders of magnitude longer than that of a Gaussian beam of comparable width, and low temporal coherence. These aspects make our laser arrays extremely versatile for microscopic and tomographic technologies requiring long and thin low-coherent light sheets, for example optical coherence tomography and light-sheet microscopy. Specifically, at the wavelength of 820 nm, a central lobe on the order of a micrometer is maintained over a millimeter-scale propagation distance. Such high resolution and large field-of-view are well suited for single-photon light-sheet microscopy using NIR fluorophores. Extension to visible or longer infrared wavelengths is promising with a suitable gain medium. In addition, semiconductor laser emitters provide a practical route toward bright chip-scale STWP sources. Based on our prior electrically pumped DFB platform, per-emitter output powers on the order of 10 mW are feasible. This feature may be beneficial for high-power imaging techniques such as two-photon light-sheet microscopy.

9. Fabrication

The fabrication process for realizing the proposed DFB laser arrays is illustrated in Fig. S10. The device is fabricated from InGaAsP/InP semiconductor material grown via metal-organic chemical vapor deposition. A negative-tone electron beam resist, XR-1541 (hydrogen silsesquioxane, HSQ) dissolved in methyl isobutylketone (MIBK), is employed as the resist material. The resist is spin-coated onto the InP wafer to achieve a thickness of 60 nm, followed by a soft bake at 180°C to enhance film adhesion (Fig. S10a). The laser arrays are patterned using electron beam lithography (Fig. S10b). The sample is then developed in a 25% tetramethylammonium hydroxide (TMAH) solution for 120 seconds and rinsed in isopropyl alcohol (IPA) for 30 seconds. The exposed HSQ remains as an etch mask for the subsequent dry-etching step. Reactive ion etching (RIE) is performed using a gas mixture of H_2 : CH_4 :Ar in a flow ratio of 40: 10: 7 sccm. The etching is conducted at a chamber pressure of 35 mTorr, with the sample biased at -450 V (Fig. S10c). To remove residual organic contamination formed during RIE, the sample undergoes oxygen plasma cleaning using an O_2 flow of 50 sccm, a bias voltage of -300 V, and a chamber pressure of 125 mTorr. The remaining HSQ mask is removed using a buffered oxide etchant (BOE) (Fig. S10d).

A lithography-assisted cleaving technique is employed to facilitate cleaving near the waveguide output facet. A negative photoresist (nLOF 2020) is spin-coated to a thickness of approximately 3 μm (Fig. S10e),

and a narrow ridge is defined as a scribing guide using i-line photolithography (Fig. S10f). The pattern is developed using AZ-MIF 300 developer for 40 seconds. A subsequent RIE is performed using an $\text{H}_2:\text{CH}_4:\text{Ar}$ gas mixture in the ratio of 8: 4: 10 sccm, with an inductively coupled plasma (ICP) power of 1000 W to define the ridge structure (Fig. S10g). The remaining photoresist is removed using oxygen plasma cleaning. The sample is then manually cleaved along the etched ridge to expose the laser facets (Fig. S10h).

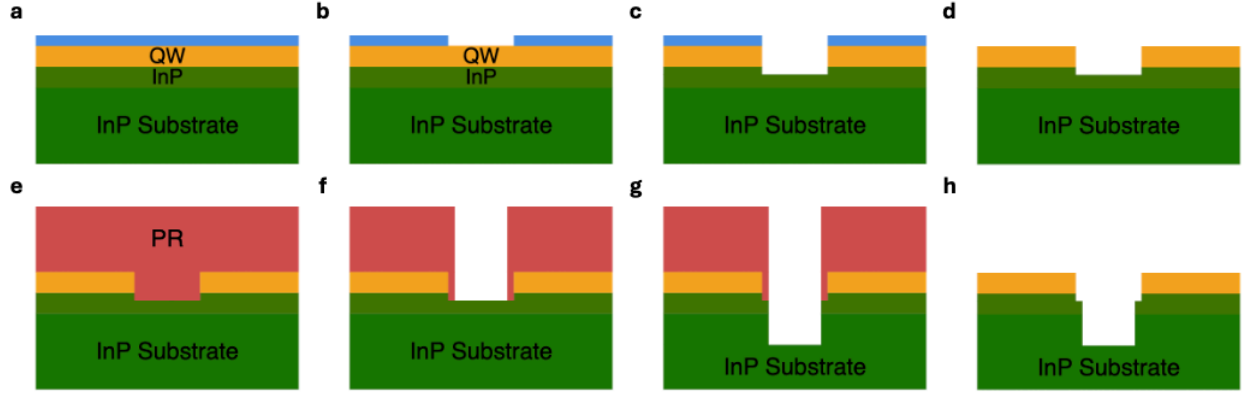


Fig. S10. Fabrication procedure for the laser arrays. (a) Spin-coating of HSQ e-beam resist onto the wafer. (b) Patterning via e-beam lithography. (c) ICP RIE to define the laser arrays. (d) Removal of the remaining HSQ mask in BOE. (e) Spin-coating of nLOF2020 photoresist onto the sample. (f) Patterning of the cleaving line via i-line lithography. (g) ICP RIE to define the ridge. (h) Removal of the remaining mask via oxygen plasma etching.

10. Characterization setup of incoherent ST fields

The fabricated samples were characterized at room temperature using a photoluminescence setup (see Fig. S11a), in which the samples were pumped by a 1064 nm pulsed laser (9 ns pulse width, 290 kHz repetition rate). The pump beam profile was shaped using a metal mask and knife edges and delivered through a $20\times$ objective (numerical aperture 0.40), which also collected the emitted photoluminescence. The sample's top surface and cleaved edge were simultaneously imaged onto an NIR camera via two cascaded $4f$ imaging systems to aid alignment and monitor edge emission. A broadband amplified spontaneous emission (ASE) source was used to illuminate the patterned cavities for pump-spot positioning, and a notch filter suppressed scattered pump light in the detection path. Emission spectra were measured with a monochromator equipped with a linear InGaAs array detector, using a 0.1 mm slit width corresponding to a spectral resolution of 0.23 nm.

To measure the time-averaged intensity distribution of the STWPs, the sample was placed at the front focal plane of an objective lens ($f = 1$ cm), allowing the incoherent ST field to form at the back focal plane. The field was relayed with a unity-magnification $4f$ system and then recorded on an InGaAs NIR camera (30 μm pixels), with an additional objective providing $5\times$ total magnification to resolve the central peak. The camera was mounted on a motorized translation stage and scanned along the optical (z) axis to capture longitudinal evolution. Temporal coherence was characterized using a Mach–Zehnder interferometer fed by another $5\times$ magnified relay of the field, with unequal magnification in the two arms ($7\times$ versus $1/5\times$) and a motorized delay stage with 500 nm positioning resolution for scanning the optical path difference (see Fig. S11b).

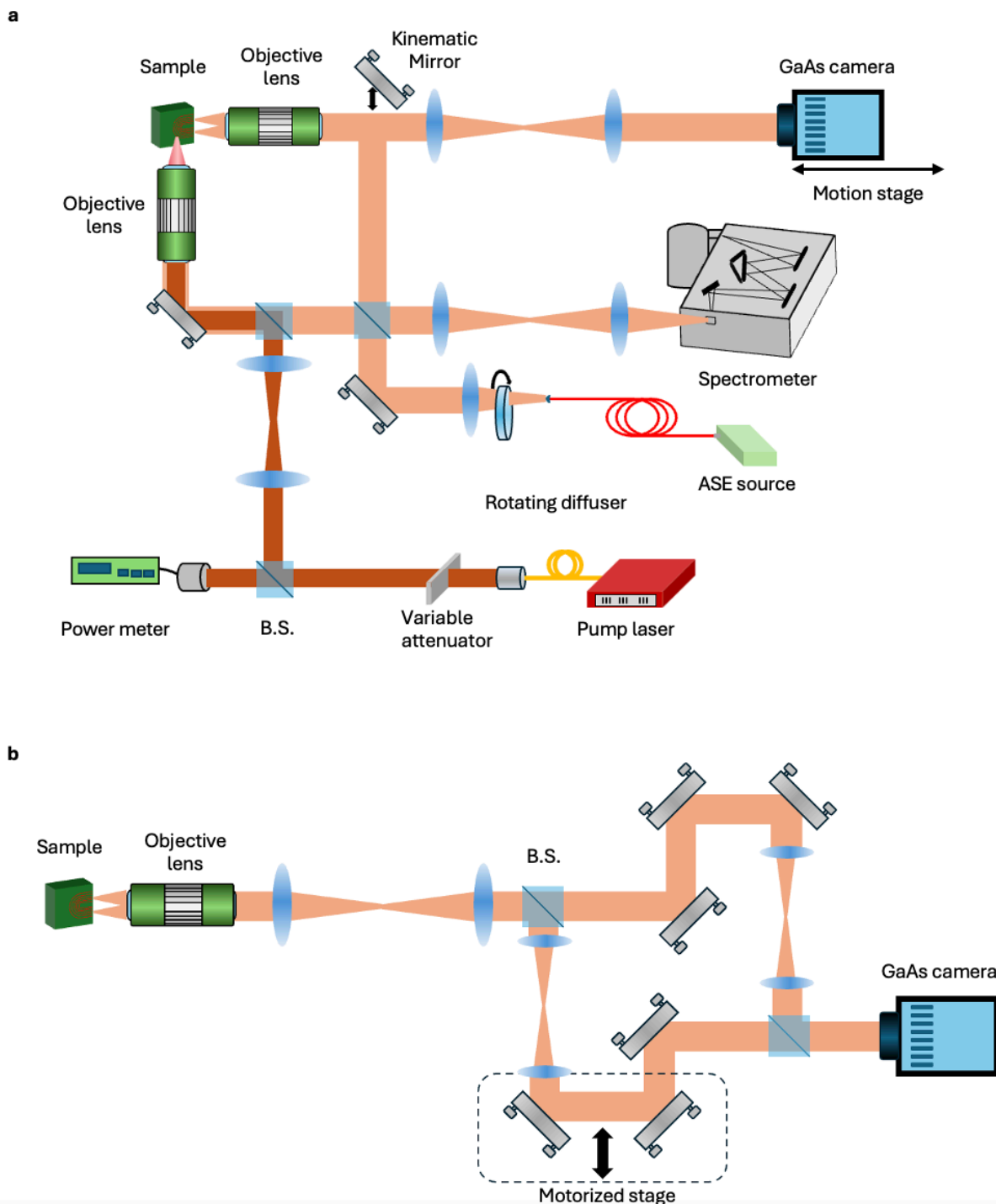


Fig. S11. Characterization setup. (a) Schematic of the photoluminescence characterization setup. The laser arrays are pumped by a pulsed laser (9 ns pulse width, 290 kHz repetition rate). The pump beam is focused onto the sample through a $0.5\times$ demagnification system. The same objective lens is used to both deliver the pump and collect the emitted photoluminescence. A second objective, positioned laterally, serves as both an imaging and Fourier lens for synthesizing the ST field. The collected emission is routed to a linear InGaAs detector array for spectral characterization or to an NIR camera for spatial intensity imaging. (b) Schematic of the Mach-Zehnder interferometer used to measure the temporal coherence of the emitted field. The pumping configuration is identical to that in panel (a).

Table S1. Comparison with existing structured beam generation technologies.

Reference	Field demonstrated	Domain	On-chip	Integrated source	Reconfigure-ability	Experimentally demonstrated
[3]	Incoherent ST fields	Spatiotemporal	No	No	Yes	Yes
[4]	Coherent STWP	Spatiotemporal	No	No	Yes	Yes
[5]	Coherent STWP	Spatiotemporal	Yes	No	Yes	No
[6]	Beam steering	Spatiotemporal	No	No	Yes	Yes
[7]	Bessel-like beams	Spatial	Yes	No	No	Yes
[8]	Airy beams	Spatial	Yes	No	No	Yes
[9]	Spatiotemporal Optical Vortices	Spatiotemporal	Yes	No	No	Yes
[10]	Spatiotemporal Optical Vortices	Spatiotemporal	No	No	No	Yes
[11]	Spatiotemporal Optical Vortices	Spatiotemporal	Yes	No	No	No
This work	Incoherent ST fields	Spatiotemporal	Yes	Yes	No	Yes

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