

Increasing Nanofiber Throughput *with a Multi-Array Emitter*



1 Why use a multi-emitter?

When scaling up electrospinning, productivity is not simply about producing more fibers, but it is also about depositing them efficiently over a larger area. Both output and deposition coverage therefore play an important role in making the process technologically and economically viable. One practical way to increase productivity is to operate several individual nozzles in parallel. In principle, each additional emitter contributes another fiber-forming jet, allowing the production rate of the nanofibrous material to increase.

2 Overview of electrospinning using a multi-array emitter

In a multi-needle setup, throughput is increased by operating several emitters in parallel. Each active emitter can form its own Taylor cone and polymer jet, allowing nanofiber production to increase approximately in proportion to the number of emitters [1].

However, adding more needles does more than simply multiply the number of jets. Unlike in a single-needle system, the electric field is determined not only by the applied voltage but also by the number, spacing, and arrangement of the emitters [2, 3]. The neighboring emitters influence one another, changing the local electric field around the polymer droplets at the needle tips.

In a single-needle setup, the charged jet is mainly shaped by the electric field between the emitter and the collector, together with Coulombic forces acting within the jet. Its whipping motion can therefore develop relatively freely in three-dimensional space, typically producing a broadly circular deposition pattern [4]. The resulting nanofibrous mat generally exhibits a Gaussian-like thickness profile: it is thickest near the center of the deposition zone and gradually becomes thinner toward the edges.

A multi-emitter system behaves differently. The electric fields generated around neighboring needles overlap and partially interfere with one another. This reduces the effective field strength at the emitter tips and introduces lateral electrostatic forces between adjacent jets. The effect is most pronounced at the outer emitters, where charge repulsion can push the jets away from the center of the array, as illustrated in Figure 1.

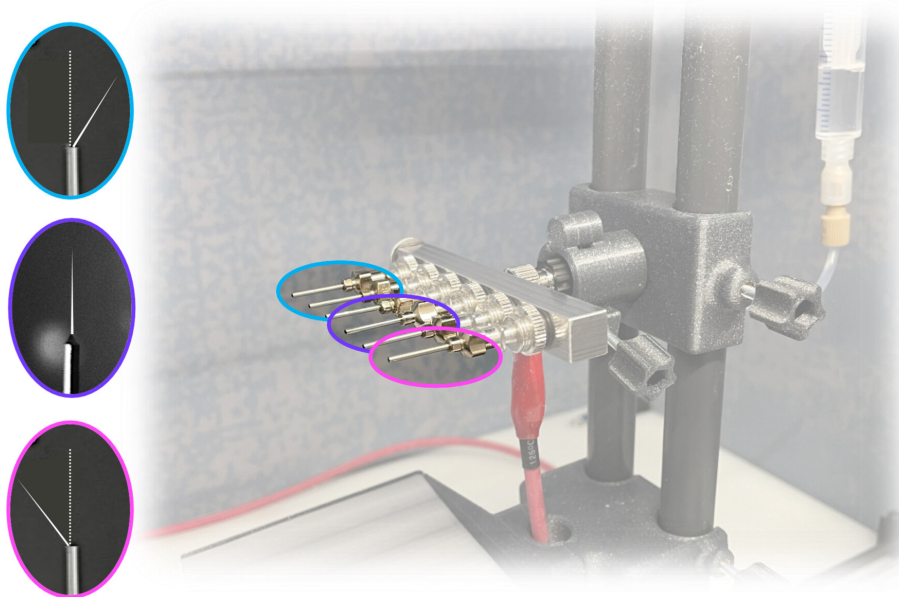
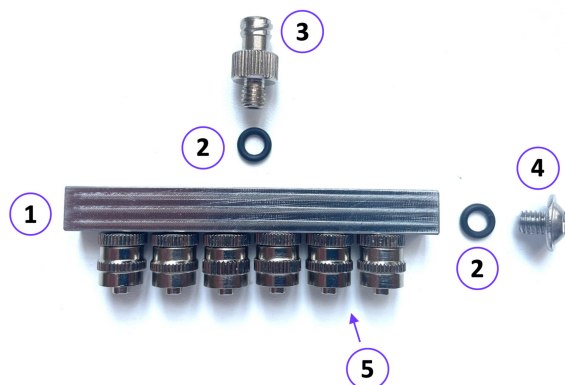


Figure 1: Jet deflection observed when using the multi-needle emitter unit of the spincube BASE system.

These interactions reshape the overall deposition zone. Instead of the predominantly circular pattern often observed with a single emitter, a multi-needle array can produce a wider, oval-shaped nanofiber deposit on a flat collector [5]. This expanded coverage is one of the practical advantages

of the multi-emitter approach, although it also makes emitter arrangement and process optimization especially important.

3 Introducing our six-needle multi-array emitter



1. Multi-array Emitter Unit
2. O-ring
3. Female Luer Adapter (inlet)
4. Stopper Screw
5. Spinneret Male Luer Lock Adapter (outlet)

Figure 2: The six-needle multi-array emitter base and its components.

switch from a single-nozzle to a six-nozzle configuration without changing the basic mounting arrangement.

Before starting the process, attach the high-voltage clip to the female Luer inlet adapter, as shown in Figure 3. Once the emitter is mounted and the electrical connection is secured, your system is ready for operation.

Our six-needle multi-array emitter combines six individual nozzles with a single stainless-steel dispensing unit. By operating all six emitters in parallel, the system is designed to provide up to a sixfold increase in nanofiber production compared with a single-nozzle configuration.

The female Luer inlet adapter (3) and the stopper (4) are attached to the main body (1) using threaded connections, while the individual nozzles are fitted to the corresponding male Luer adapters (5). Luer-lock nozzles may be used when a more secure and mechanically stable connection is preferred.

4 Basic Setup and Operation

The complete multi-array unit mounts to the same connection point on the spincube tower as a conventional single-nozzle emitter. From the instrument's perspective, it therefore functions as one integrated emitter module, allowing users to

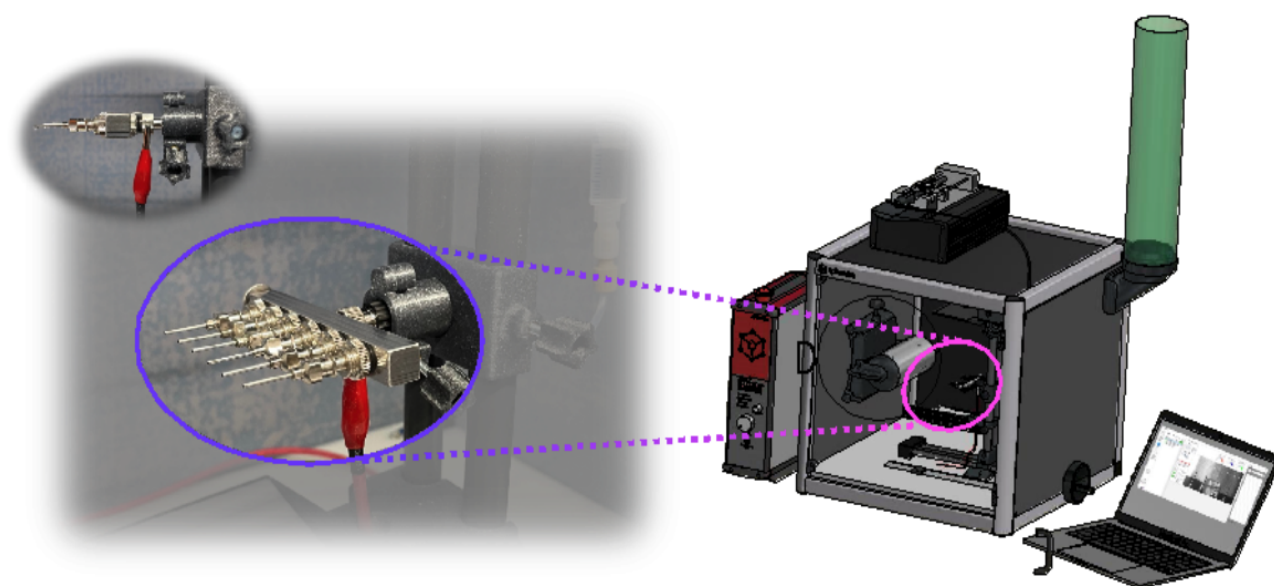


Figure 3: The six-needle multi-array emitter installed in the spincube BASE electrospinner.

5 Seeing the Multi-Emitter in Action

The following example illustrates the operation of the six-needle multi-array emitter using a conventional, readily electrospinnable PVA precursor solution. The formulation contained 8 w/w% PVA with a molecular weight of 205 kDa in water.

The emitter was tested at total flow rates of 30, 42, 60, 72, and 90 $\mu\text{L}/\text{min}$, corresponding to 5, 7, 10, 12, and 15 $\mu\text{L}/\text{min}$ through each individual G18 nozzle. At a 15 cm emitter-to-collector distance and under ambient conditions, stable fiber formation was achieved by adjusting the applied voltage within the 20–32 kV range. Across the investigated flow rates, the six-nozzle configuration provided a relative throughput approaching six times that of the corresponding single-nozzle process, as shown in Figure 4.

When a flat collector is used, the applied voltage also has a pronounced effect on the shape and position of the deposited nanofibrous material. Compared with single-needle electrospinning, the overlapping electric fields around the six emitters create several distinct and voltage-dependent deposition zones, as shown in Figure 5.

The multi-emitter setup generally requires a higher applied voltage than a single-nozzle configuration. Because the neighboring emitters partially shield and distort one another's electric fields, the effective field strength at each nozzle tip is reduced. A higher voltage is therefore required to reach the critical field strength needed to initiate and sustain stable fiber-forming jets.

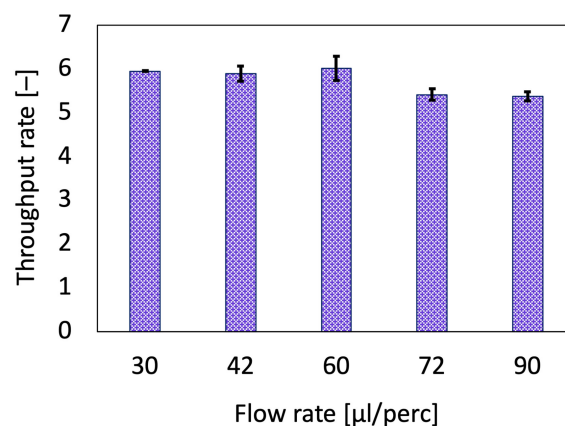


Figure 4: Relative throughput of the multi-emitter array, normalized to the single-needle emitter, as a function of the total precursor flow rate.

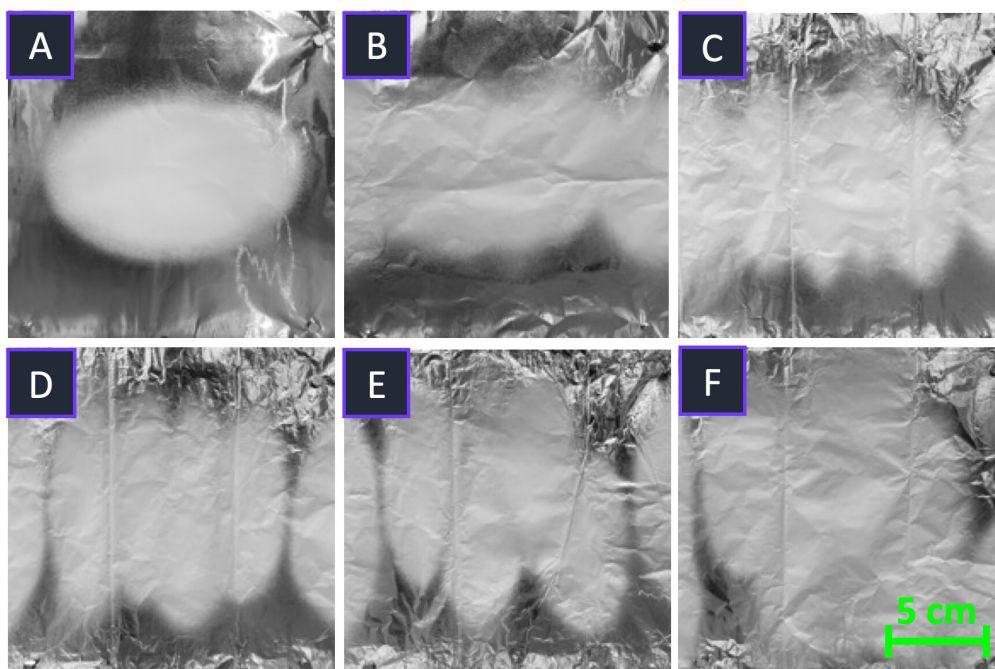


Figure 5: Effect of the applied voltage on nanofiber deposition (**A:** 17.5 kV, single-needle reference; **B:** 20 kV; **C:** 22 kV; **D:** 26 kV; **E:** 27 kV; and **F:** 32 kV).

Despite the visible changes in the macroscopic deposition pattern, scanning electron microscopy revealed no substantial deformations in fiber morphology. As shown in Figure 6, the samples consisted mostly of randomly oriented, defect-free fibers. Only occasional thicker fibers were observed, and no major morphological differences were detected between the investigated voltage settings.

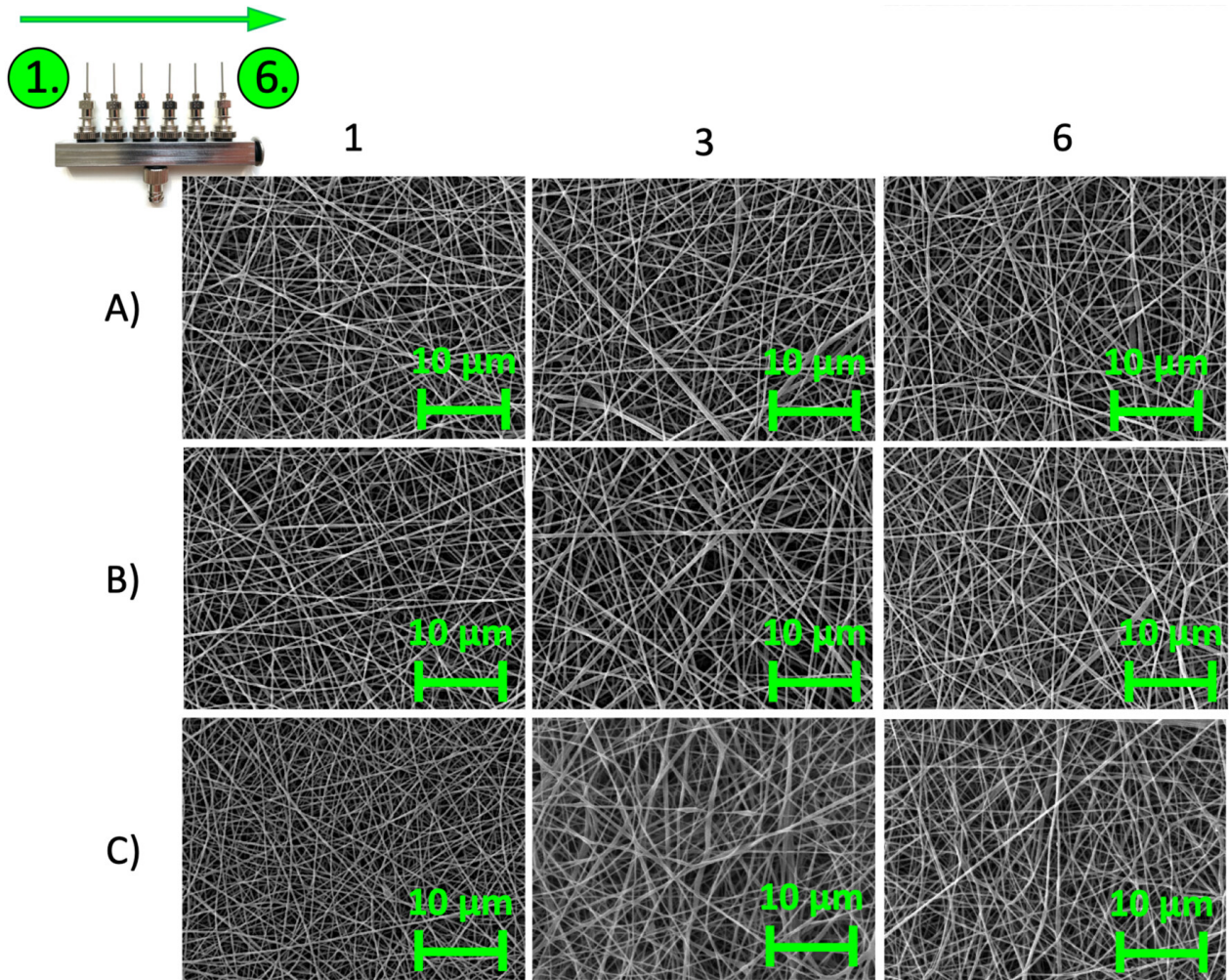


Figure 6: SEM images of PVA nanofibers produced with the multi-emitter at different applied voltages and a magnification of $2000\times$ (**a:** 20 kV; **b:** 26 kV; and **c:** 32 kV).

Fiber diameter was evaluated at six distinct sampling locations across the deposited mats. At the lower applied voltages, the average fiber diameter remained relatively uniform across the sampling positions, as shown in Figure 7a and b. The measured values differed slightly from those obtained with the single-needle reference, but the overall diameter distribution remained spatially homogeneous.

At the higher investigated voltages, however, the fiber diameter became less uniform across the deposition area. Elevated average diameters were measured in regions associated with the central emitters, with these values being closer in diameter to those of the single-needle references (Figure 7b and c). This suggests that increasing the applied voltage can influence not only the macroscopic deposition pattern but also the spatial uniformity of the resulting fiber dimensions.

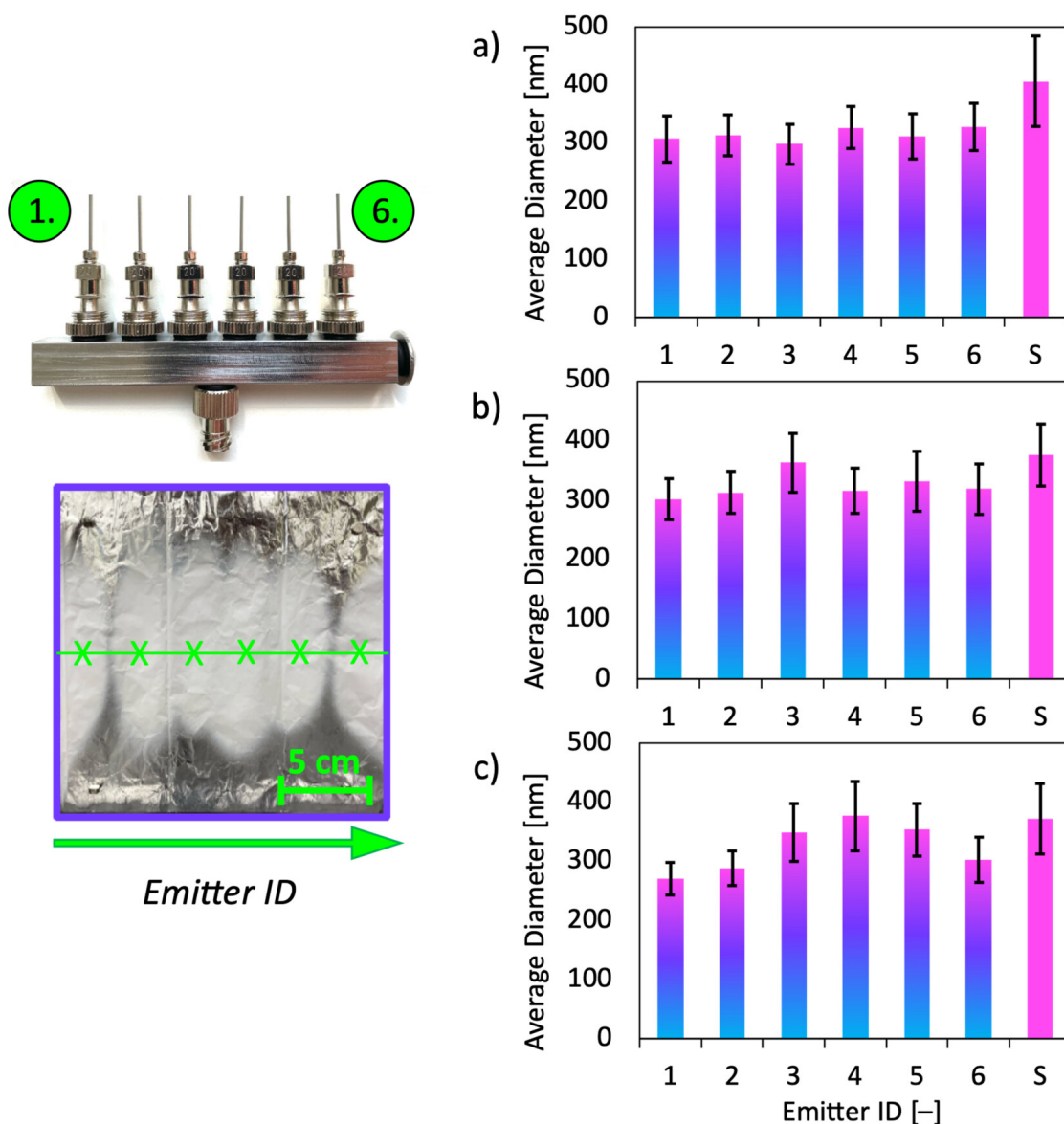


Figure 7: Average fiber diameter of PVA nanofibers produced with the multi-emitter at different applied voltages (**a**: 20 kV; **b**: 26 kV; **c**: 32 kV; and **S**: single-needle reference).

5.1 Conclusion

Overall, the results demonstrate that increasing the number of active emitters produced a clear increase in nanofiber output, with the six-needle configuration approaching a sixfold yield.

Successful scale-up however depends on choosing suitable process settings for the formulation and collector setup. At higher flow rates especially, adjusting the voltage and collector setup helps maintain stable fiber formation and efficient deposition.

References

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