Supporting Information for
“Cooperative Thermal-Electric Field Control of Infrared Modulation Using a Vanadium Dioxide Film-based Modulator”

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S1. Experiment setup for comparative thermal-electric field control

Direct-current stable power apply was used to provide thermal or electric field. Digital function generator (RIGOL DG4202) with two channels was utilized to generate periodic control signal. To modify the applied $V_T$ and $V_E$, power amplifier (OPA541) was used.

Figure S1. (a) Experiment setup for comparative thermal-electric field control. (b) physical images of the electrode and micro-heater.
S2. Film thickness measured by scanning electron microscopy

Figure S2. SEM images. (a) Top view image. (b) Side view image showing the thickness of VO$_2$ film.
S3. Surface temperature detected by infrared image.

Figure S3. The infrared camera captured images displaying the surface temperature, using an emission rate of 0.65, which is intended for smooth surfaces.
S4. Electric field distribution within VO$_2$ film

Fig S4. Simulations showing electric field variations within VO$_2$ film at 28 V applied bias. (with conductivity of VO$_2$ film set as 50, 500, and 5000 S/m).
S5. Recovering time of IR modulation under simultaneous control of $V_E$ and $V_T$

Figure S5. Recovering time of IR transmittance after 5 cycles responding and recovering. ($V_E = 32$ V, $V_T = 1.4$ V). The data demonstrates that after 5 cycles ($V_E = 32$ V, $V_T = 1.4$ V), the recovery time is increased to approximately 79 seconds, indicating that it is not possible to fully recover to the initial transmittance within the 50-second cooling period.