Millimeter wave (mmWave) communication is a promising technology for future wireless systems, while one practical challenge is to achieve its large-antenna gains with only limited radio frequency (RF) chains for cost-effective implementation. To this end, we study in this paper a new lens antenna array enabled mmWave multiple-input multiple-output (MIMO) communication system. We first show that the array response of lens antenna arrays follows a "sinc" function, where the antenna element with the peak response is determined by the angle of arrival (AoA)/departure (AoD) of the received/transmitted signal. By exploiting this unique property along with the multi-path sparsity of mmWave channels, we propose a novel low-cost and capacity-achieving spatial multiplexing scheme for both narrow-band and wide-band mmWave communications, termed path division multiplexing (PDM), where parallel data streams are transmitted over different propagation paths with simple per-path processing. We further propose a simple path grouping technique with group-based small-scale MIMO processing to effectively mitigate the inter-stream interference due to similar AoAs/AoDs. Numerical results are provided to compare the performance of the proposed mmWave lens MIMO against the conventional MIMO with uniform planar arrays (UPAs) and hybrid analog/digital processing. It is shown that the proposed design achieves significant throughput gains as well as complexity and cost reductions, thus leading to a promising new paradigm for mmWave MIMO communications.